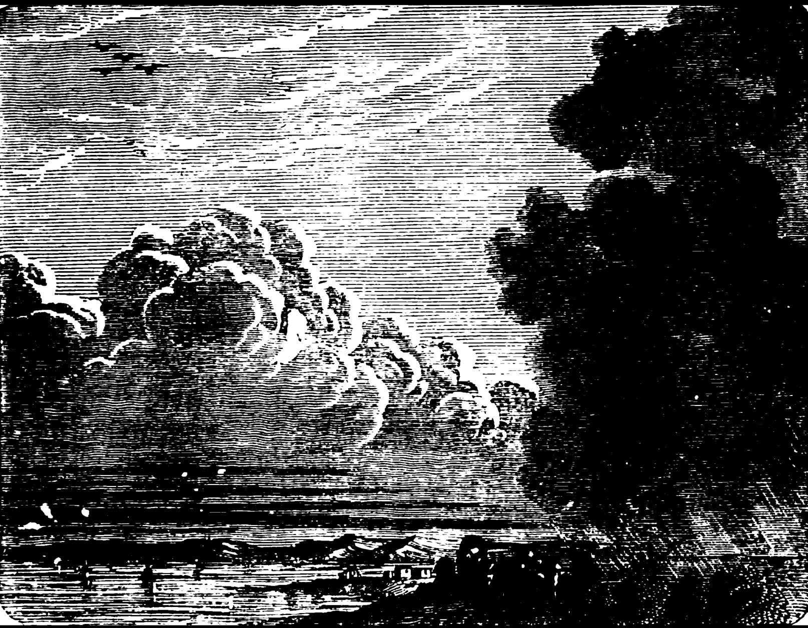

Lessons in elementary mechanics

W. H. Grieve

LESSONS

IN

ELEMENTARY MECHANICS

FIRST STAGE

BY

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Demonstrator in Science for the London School Board.

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PREFACE.

DURING the past five years the attention of the public has been forcibly directed to the great advantages which will accrue to us as a nation from some well-defined system of Technical Education.

The author, feeling persuaded that, for such a course to be thoroughly successful, the rudiments of science must be mastered in our Elementary Schools, has issued in three separate text-books the three stages of Mechanics or Elementary Natural Philosophy.

A very large proportion of the illustrations have been engraved expressly for this book, the remainder being borrowed from the following works, viz.: Ganot's 'Natural Philosophy,' Ganot's 'Physics,' Goodeve's 'Mechanism,' Furneaux's 'Chemistry,' Tate's 'Mechanism,' Thornton's 'Physiography,' Wright's 'Sound, Light, and Heat.'

W. H G.

EAST DULWICH: *September*, 1888.

MECHANICS.

First Stage.

Matter in three states: solids, liquids, gases.
Mechanical properties peculiar to each state.
Matter is porous, compressible, elastic.
Measurement as practised by mechanics.
Measures of length, time, velocity, and space.

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LESSONS

IN

ELEMENTARY MECHANICS.

CHAPTER I.

MATTER.

1. Matter—2. Its existence, as revealed to us by our senses—3. General properties of matter, viz. *extension*, *divisibility*, *weight*, *compressibility*, *elasticity*, and *porosity*—4. Matter is indestructible.

1. **Matter.**—Here we have a word of six letters, and yet the whole of this book will not be found sufficient to explain to the young reader all that can be said about it.

What, then, does it mean?

Some writers will tell you that **matter is anything which can be acted upon by force**; but we prefer the more homely definition, viz. **any substance which has an existence.**

2. **Its Existence, as revealed to us by our Senses.**—Whenever we become acquainted with the existence of a body it will be by the aid of the *sense of sight*, *touch*, *taste*, *smelling*, or *hearing*.

Let us take a few illustrations.

I have in my hand an indiarubber ball. How do I know this?

I call into exercise the *sense* of *sight*, which reveals to me its shape as well as its colour.

Or, if I take two bottles containing *ether* and *water*.

The *sense* of *sight* no longer assists me in determining which is the *water* or which is the *ether*.

I am therefore compelled to call into action the *sense* of *smelling*.

Again, I offer a blind man a piece of *glass* and a piece of *wood*, and ask him to tell me which of the two is *glass*.

The *sense* of *sight* he does not possess; the *sense* of *smelling* is of no avail; it will be his *sense* of *touch* that will enable him to answer my question correctly.

Further, we know the air we breathe has an existence, not because we can see it or taste it, but because we can feel it and hear it.

In the same manner, we do not distinguish salt from sugar merely by looking at them. By applying the tongue to the sugar or to the salt you soon know which of the two is the sugar. Thus, balls, ether, water, wood, glass, air, salt, sugar may all be given as illustrations of **matter**.

3. **General Properties of Matter.**—On one occasion I asked a boy what he meant by the word *property*? Instantly he replied, 'That which belongs to a person or to a thing.'

In a certain sense this is true.

Now, what is there about a piece of glass that we do not find in a piece of wood?

First, we can see through the glass, which we cannot do through the wood. We therefore say the glass is transparent, and the wood is opaque.

Hence **transparency** is a **property** or **quality** which belongs to glass; and **opacity** is a **property** or **quality** which belongs to wood.

Again, the glass if thrown on the ground will break; not so with the wood.

This is because glass is *brittle*.

Brittleness is therefore a **property** possessed by the glass; and **toughness** is a **property** possessed by the wood.

Similarly, a boy may have red or jet-black hair. This also is a property, viz. that of **colour**.

We want, however, to give the word **property** a much wider meaning. Bodies may have **properties** in common as well as possessing these particular **properties** which we have just mentioned; in which case the **properties** would be termed **general**.

For instance, we cannot call **brittleness** a **general property**,

for it is not possessed by all bodies ; neither would you say **transparency** was **general**, for we cannot see through every body.

Such properties are termed **special** or **specific**.

On the other hand, **extension, divisibility, weight, compressibility, elasticity,** and **porosity** are **general** ; for, on very careful investigation, we find that there is no kind of matter which does not possess them, even though it may be but in a limited degree.

Owing to the great importance of these **properties** we shall take them singly.

First, there is the **property** of **extension.** Now, this is a word which a boy will turn over and over again in his mind, and will wonder what it can mean.

When I place my hand in a tumbler of water I observe the water to run over. This is so because my hand takes up a certain amount of room.

Room then is the simplest word which we can use to convey the idea that every body, whether *solid*, *liquid*, or *gas*, takes up a certain amount of space.

When we consider the **property** of **extension** in one direction only, we call it **length**; if in two directions, viz. the *length* and *breadth* of the body, then **surface** conveys the idea of **extension**; but when the three measurements of a body are considered, viz. *length*, *breadth*, and *thickness*, **volume,** or **space occupied,** expresses the **property** of **extension.**

Secondly. **Divisibility** is a property in common to all bodies.

To divide a body into its component parts is one of the first acts of every child.

Give him an apple and a knife.

It is not very long before you see the apple strewn upon the floor in dozens of pieces.

Or, if he were to place a piece of loaf-sugar into his tea, how natural it is for him to stir and stir the tea over and over again.

Why does he do it ?

Simply to divide and subdivide the sugar into thousands or perhaps tens of thousands of pieces.

Now, this dividing of bodies into very small parts applies to every substance. The tenth part of a grain of musk was known on one occasion to scent a gentleman's study for upwards of two years.

A small piece of magenta or a drop of a powerful dye

placed in a test-tube containing water will be sufficient to colour the whole liquid.

If the water in question be supposed to be made up of ten thousand drops, it is clear that there will be found in each drop only the ten-thousandth part of the piece of magenta, or the ten-thousandth part of the drop of dye.

In the art of gold-beating leaves are obtained whose thicknesses do not exceed the two hundred and ninety-thousandth part of an inch.

Similarly, in obtaining Dutch metal from brass by hammering, the leaves often have but the two hundred and fifty-thousandth part of an inch for their thickness.

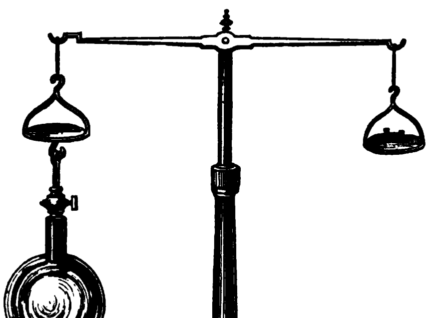
In fact, whatever substance you may select, its division is very soon accomplished.

Thirdly. **Weight** is a **property** every body possesses.

It is related of Sir Isaac Newton that for many years he was not quite clear as to the reason why a stone should fall *towards* the earth instead of falling *away from it.*

After considerable amount of thought he came to the conclusion that the earth acted upon every body outside itself in just the same manner as a magnet attracts a needle.

FIG. 1.



This is not only true of a solid or of a liquid, but it is also true with respect to gases.

Water, if upset, naturally falls to the floor, and not to the ceiling, thus showing that the action of the earth upon water is one of attraction downwards.

To prove this for *gases* we select a glass globe, Fig. 1, which has a stop-cock fitted to it for the purpose of opening or shutting off communication with the interior of an air-pump.

When emptied of its air the globe is weighed by means of a very delicate balance.

If the air is then admitted, the scale-pan to which the globe is attached descends, showing that the earth attracts the globe more when it is full of air than when it is empty.

Thus, then, **air** has **weight.**

With the apparatus illustrated in Fig. 1 we have often shown experimentally a difference of 16 grains in the weight of the globe before and after it has been deprived of its air.

If the globe contained 100 cubic inches the weight of the air within would be about 31 grains; if, however, hydrogen gas were selected, which is the lightest of all gases, we should then have a weight of two grains only.

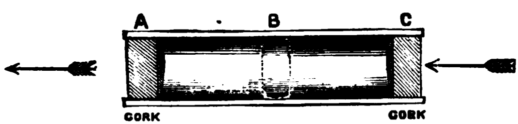
Fourthly. **Compressibility,** or the **property** a body possesses when it can be reduced in size, applies to all kinds of matter. A sponge, when held in the hand, can soon be reduced into a very small space, as also a piece of new bread.

But this **property** can be more clearly exhibited when we deal with gases.

Take, for example, a child's pop-gun, Fig. 2, and fit corks into the two ends.

Now, when an attempt is made to force in one of the corks the air within is of necessity reduced in size; which, being **elastic,** tries to regain its original volume, and in so doing drives out the cork at the opposite end.

FIG. 2.



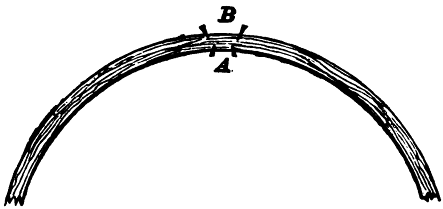
The **compressibility** of liquids being so slight, it was for many years considered impossible to reduce them in volume. In more recent experiments water has been slightly **compressed.**

Oersted, a Swedish philosopher, succeeded in compressing distilled water by one-twenty thousandth part of its volume, by which we mean that water occupying 20,000 cubic inches was reduced to 19,999 cubic inches.

Fifthly. **Elasticity** is a property seen alike in *solid*, *liquid*, and *gas* ; and, therefore, must be classed as a **general property.**

It would be well here to to state what we mean by **elasticity,** especially as beginners seem to think that it is a **property** a body possesses when it can be stretched.

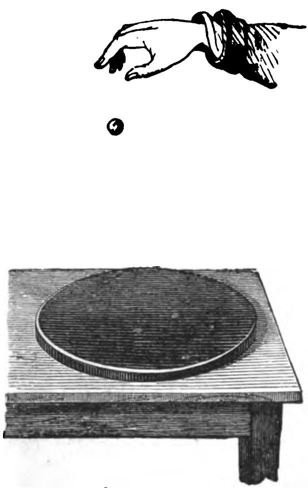
Fig. 3.



By **elasticity** we not only mean that the body may be extended, but that it has the power to return to its former shape after having been pulled out of shape.

A very common illustration of this property is that of a piece of whalebone when bent, Fig. 3. How quickly it returns to its straight condition when once it is set free.

Fig. 4.



Another more telling experiment, perhaps, is the elasticity possessed by a glass alley.

If it be allowed to fall on to a slab of polished marble (Fig. 4) covered with ink, a circular impression is made on the slab much larger than would have been the case had the alley simply rested upon it.

The conclusion, therefore, to be drawn from this is, that the alley in striking the slab became flat, and that it rebounded while returning to its round state by virtue of the elasticity it possessed.

A child's air-balloon may be employed to illustrate the **elasticity** of air or coal-gas.

When thrown upon the table it immediately flies upward. Why?

In striking the table a part of the balloon is flattened ; but

the gas within being **elastic** tends to regain its original size, and in so doing causes the balloon to rebound.

Sixthly. **Porosity**, or the property which a body possesses when it contains **pores** or *small intervals* between its material particles.

The existence of pores in the human frame is familiar to all, especially after running, when large drops of perspiration are seen to stand out very conspicuously upon the skin.

Whence come these drops?

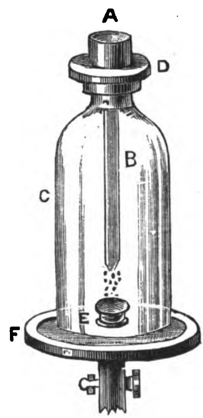
From the interior of the body, through the **pores** of the skin.

Some years ago in Florence an experiment was tried upon gold to see if it were **porous.**

A hollow globe of that metal was filled with water, and then sealed up very firmly.

Great pressure was exerted upon the ball to see if the water within could be compressed, with the result that the outside of the ball was coated with a fine dew; showing that the water within had, under great pressure, been forced through the small **pores** of the globe.

Fig. 5.



A very taking class experiment is this. A piece of thick Malacca cane, having been provided with a cup of boxwood at one end, is placed over the open mouth of a glass receiver which stands upon the plate of an air-pump. Mercury having been put into the cup, the air from the receiver is then extracted. From the pointed end of the cane, which is within the receiver, little drops of mercury are seen to fall, having travelled from one end of the cane to the other through its pores. This silvery shower of mercury takes place by reason of the pressure of the atmosphere, which forces the mercury through the whole length of the cane.

In Fig 5, B represents a piece of Malacca cane, to which has been fitted a boxwood cup A. C is a glass receiver standing upon the bed-plate F of an air-pump.

D is a brass flange turned very smooth and then surfaced

very true. Now, when placed in position (as seen in the figure), mercury is poured into the cup A, and the air is taken out of the receiver C by means of the air-pump.

Very quickly small drops of mercury are seen to fall from the end of the cane into the cup E, it having travelled the whole length of the cane.

Sometimes the **pores** are so small that they cannot be seen, even with the most powerful microscope; but we know of their existence from the fact that the body is *compressible*; and this could not be if there were no empty spaces within to fill up.

Scientific men distinguish the **pores** that are seen from those that are not seen by the terms **sensible** and **physical**; thus, the **pores** that are seen in sponge, pumice-stone, cork, &c., we should call **sensible**; while the **pores** of a substance, such as glass, through which no force has been found sufficient to send water we term **physical**.

4. **Matter is indestructible.**—When a substance disappears from our view we often say it is destroyed; for instance, a lump of coal burning in a fire-grate gradually gets less and less, until, as coal, it ceases to be visible.

Is the **matter** of which the coal is composed put out of existence?

We think not. If we consider only the carbon of the coal, we find it again, joined with the oxygen of the air, in the form of carbonic acid gas.

Or, when considering the burning of a candle we observe the candle diminishing in size. What becomes of the **matter** in the candle? First, the *hydrogen* contained in the tallow unites with the *oxygen* of the air to form *water*; and secondly, the *carbon* in the tallow unites with the *oxygen* of the air to form *carbonic acid gas.*

QUESTIONS UPON THE FIRST CHAPTER.

Ques. 1. If a pint of water be mixed with a pint of alcohol, the volume of the mixture is less than two pints. How do you account for this?

Ques. 2. Show clearly why a child's ball inflated with air rebounds when thrown upon the ground.

Ques. 3. What do you understand by *elasticity*?

Ques. 4. What explanation can you offer of the fact that a bent piece of whalebone tends to straighten itself?

Ques. 5. What becomes of the water poured into a glass full of sand?

Ques. 6. What does the *indestructibility* of matter mean? Show that matter is indestructible, using as an example the combustion of coal in a fire-grate.

Ques. 7. What do you understand by *porosity*? How is it connected with the *compressibility* of matter?

Ques. 8. Describe the properties of salt, treacle, lead, and glass.

Ques. 9. Compare the properties of a lump of sugar and a lump of lard.

Ques. 10. Describe the properties of iron, sugar, chalk, and mercury.

Ques. 11. Give an experiment to show that solid bodies possess elasticity.

Ques. 12. There are two kinds of *pores* to be found; explain this, and give examples.

Ques. 13. How could you find the volume of the *pores* of a piece of chalk?

Ques. 14. How can you show that air has weight?

Ques. 15. What are the general properties of matter? Give examples of substances possessing these properties.

Ques. 16. What is the cause of weight?

Ques. 17. What do you mean by the *divisibility* of matter? Give some examples showing the extent to which matter is divisible.

Ques. 18. How is it that a drop of dye can colour a large quantity of water?

Ques. 19. I drop a lump of sugar in my tea; state clearly what takes place. Why must I stir my tea before I drink it?

CHAPTER II.

THE THREE STATES IN WHICH MATTER EXISTS.

5. The solid state—6. The liquid state—7. The gaseous state—8. Change of matter from one state to another—9. Elements and compounds—10. Fluids.

5. **The Solid State.**—Having made ourselves familiar with the word **matter,** let us consider where **matter** is found and how it is found.

In the first place we notice that throughout the whole universe matter is met with on every hand, while in the second place it presents itself either as **a solid, a liquid, or a gas.**

Thus, then, all substances, or all classes of **matter,** will be found in one or other of these three forms.

What then is the peculiar feature about **a solid?**

We observe that, unless subjected to pressure, **solids always occupy the same space** and **retain the same shape.**

In illustration of this, suppose you take an indiarubber ball which is resting upon the table; you observe that it has a round shape. Now place it in a square box; no alteration in the shape of the ball will take place, nor will it occupy any more room there than it did when resting upon the table.

6. **The Liquid State.**—What has been said of a **solid** is not true of a liquid.

Liquids have no shape of their own, but take the shape of the vessels which contain them; at the same time **they occupy** the **same amount** of **space.**

Here then is a *likeness* between a solid and a liquid, as well as a point in which they *differ.*

Let us see how this can be.

Suppose you pour tea from a teapot into a teacup, and then from the cup into a saucer.

Each time you observe the liquid **changing its form,** and taking the shape of the vessel that is holding it.

But does it take up more room in the teapot than in the saucer? No. No one has succeeded in filling a quart jug from a pint measure, nor have they squeezed a pint of milk into a can which holds but a half-pint.

From these observations we conclude that while liquids may change their form, they do not occupy more nor less space in being transferred from one vessel to another.

7. **The Gaseous State.**—In this form the particles of matter appear to be in a continual state of movement, trying to push each other farther and farther away.

For this reason **gases have no shape of their own,** nor are they confined to **one particular size.**

This property which gases possess of occupying more space is termed the **expansibility** of **gases.**

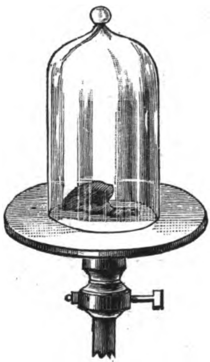
It is often illustrated by the following experiment.

A bladder partly filled with air (Fig. 6) and tightly tied at the neck is placed under the receiver of an air-pump. If the air within the receiver be then pumped out by means of the pump, the bladder will be seen to swell out (Fig. 7), showing the tendency of the air inside the bladder to occupy a larger amount of room.

When the air is again admitted into the receiver the bladder returns to its original size, thus proving that air is not only *expansible* but also *compressible.*

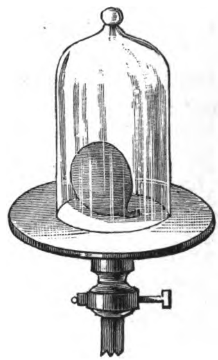
Suppose, however, that the bladder were filled with air before it is placed under the receiver of the air-pump; then by virtue of its *expansibility* it will cause the bladder to burst.

FIG. 6.



Bladder partly filled with air.

FIG. 7.



Bladder inflated by pumping the air out of the receiver.

8. **Change of Matter from one State to another.**—It is very important to notice that by the application of heat, or by the withdrawal of heat, the state in which matter is found may be changed.

For instance, we all know what is the effect of applying heat to water—how after a time the whole of the water will disappear from view.

It no longer exists in the liquid state, but will be found in the form of a vapour, and exhibiting the properties of a gas.

On the other hand, if heat be withdrawn from a vapour it is converted into a liquid, or, if heat be taken from a liquid, the liquid becomes solid.

The three states of matter therefore depend upon the amount of heat present at any given time.

The substances which can exist in all three states, and which are most frequently met with, are *water*, *sulphur*, and *mercury*.

Vapour, dew, cloud, steam, mist, hail, ice, snow, and rain are all different forms of water.

It will be interesting to inquire to which of the three states of matter they respectively belong.

First, then, a **vapour** is the **gas** into which a liquid is converted by evaporation; or, as some writers put it, a **vapour** is the **gas** obtained from a liquid before it reaches its boiling-point, thus showing that evaporation takes place at all temperatures.

Again, **dew** is simply watery vapour which has condensed upon bodies during the night in the form of very small globules.

The explanation we give is this.

After sunset the different objects on the earth's surface begin to part with their heat which they have taken up during the day.

The layer of air which is immediately in contact with these objects then deposits a portion of the vapour which it contains.

As an illustration of this, if a piece of glass be brought near to the steam issuing from a tea-kettle, it is at once covered with moisture; or, when one is standing close to the window he observes how soon the glass becomes bedimmed with a kind of moisture.

In both these cases it is explained by the sudden fall of temperature of the vapour as it comes in contact with a cold surface.

Cloud.—This is a name given to watery vapour, which, owing to its lightness, has risen to the higher regions of the atmosphere, and there become condensed into very minute drops.

Huxley very beautifully puts it: '**A cloud** is a **fog** floating high up in the air: while a **fog** is a **cloud** resting upon the earth's surface.' From this we may infer that **clouds** and **fogs** proceed from the same cause, and only differ in their respective situations.

As the appearance of clouds is a very common topic for conversation we will here give the usual names by which they may be distinguished.

First, there is the **cirrus**, which consists of small white clouds, commonly called by seafaring people *mares' tails.*

These float very high indeed, often to the height of 20,000 feet.

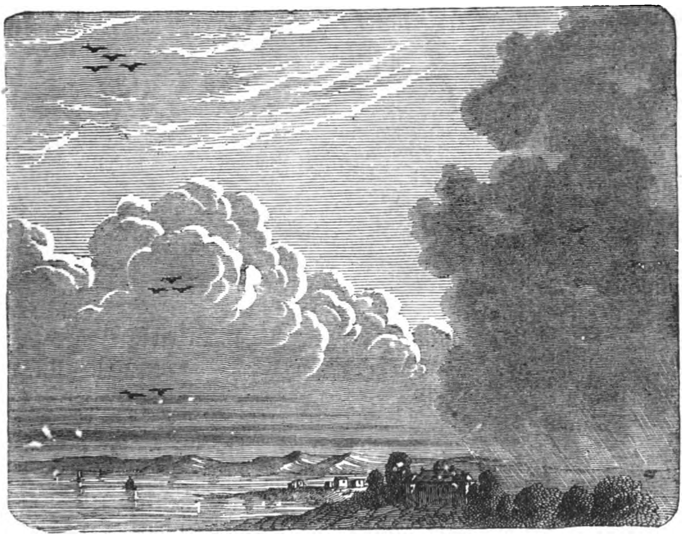
Secondly, the **cumulus**, or spherical clouds, remind us of a number of huge snowballs piled one on the other.

Thirdly, **stratus clouds**, so called because they run in horizontal strips.

Lastly, the **nimbus**, or dark rain clouds.

In the sketch, Fig. 8, those dark clouds to the right we should call **nimbus** clouds; those fleecy clouds at the top, **cirrus**; those near the bottom, **stratus**; and those at the centre, **cumulus clouds.**

FIG. 8.



Steam.—This is simply the vapour obtained from water *after* it has reached its boiling-point.

Mist.—When aqueous vapour is condensed in the midst of the air without coming into contact with any cold surface, the product is termed a **mist.**

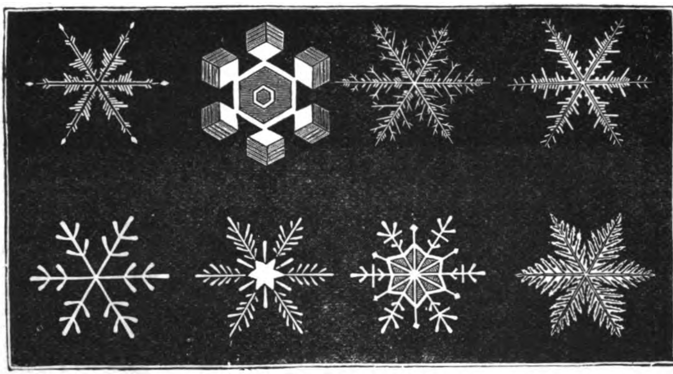
In fact, a **mist** is a very thin fog.

Hail is the solid form taken up by rain drops in their fall from the higher regions of the atmosphere to the earth.

For this to take place we have to assume the layers of air

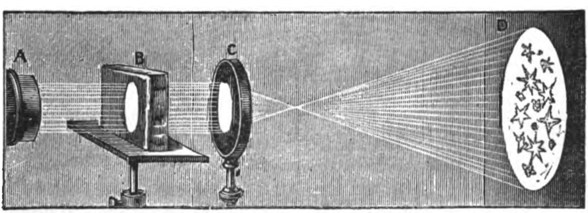
through which they pass to be colder than those in which the drops were first formed. In fine summer weather a freezing temperature exists at a height of 10,000 feet, when it is no unusual thing for a colder layer of air to underlie a warmer one ; although as a general rule the temperature diminishes in ascending.

FIG. 9.



Snow is water solidified in the form of crystals, each resembling a star, for which reason they are termed *stellate* crystals.

FIG. 10.



In the sketch, Fig. 9, some of the forms of snow-crystals are given. Professor Tyndall in one of his experiments beautifully illustrates this. The experiment consists in passing the light of the sun through a sheet of ice.

A lens C, Fig. 10, placed behind the ice B, collects the rays of light as they pass through, and then projects on to a screen D the image of what is formed in the centre of the block of ice.

Ice is nothing more nor less than a collection of snow-crystals.

Rain.—By the constant condensation of the particles of aqueous vapour the small ones unite to form large and heavy drops, which being heavier than the surrounding air fall towards the earth.

9. **Elements and Compounds.**—For many years our forefathers were under the impression that such substances as *air* and *water* were simple; that is, that nothing could be obtained from water but water, and nothing from air but air.

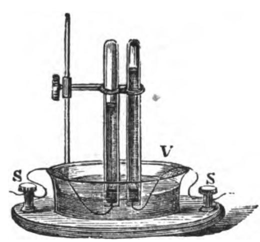
Chemists, however, have shown us that this is not true: for from water we can obtain two gases, oxygen and hydrogen, while by analysing the air we learn that the two gases oxygen and nitrogen are mechanically mixed in about the proportion of 1 to 4.

Of course, there are other substances in the air besides these two gases, but only to a slight degree.

To distinguish *air* and *water* from those ingredients of which they are composed the terms **elements** and **compounds** were introduced.

An element therefore may be defined as that kind of matter from which nothing new can be obtained; whereas a **compound** is the substance formed by the union of two or more elements in such a manner that its properties differ from those of the elements of which it is composed.

FIG. 11.



Chemists differ in their accounts of the number of elements; but if we set the number down at sixty-five we shall not be far from the truth.

Under ordinary conditions five are found as gases, two in a liquid form, and the remainder, fifty-eight, are solids.

In Fig. 11 the apparatus usually employed for decomposing water is shown.

It consists of two test-tubes which have been filled with water and then inverted over a trough of water v.

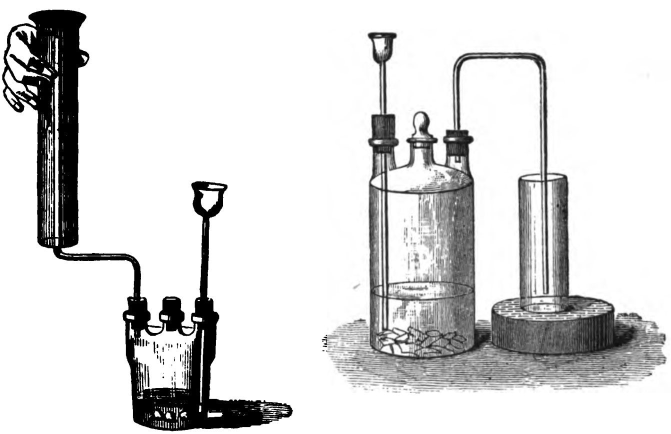
Wires leading from a galvanic battery pass through the screws s s, on either side, into the trough and enter the test-tubes, and to these ends pieces of platinum are attached. On setting the battery to work, bubbles of gas are seen to rise from these pieces of platinum ; at the same time the water within the test-tubes is observed to fall, having been displaced by the gases ; while the quantity of gas collected in the one tube is just double that in the other. If the gases collected in the two tubes be tested, the one with the greater amount will be found to contain hydrogen gas, while the other answers the test for oxygen. Thus water is proved to be made up of two gases, viz. two parts hydrogen to one of oxygen.

10. **Fluids.**—This is a word which has a much wider meaning than the word **liquid.**

It is derived from the Latin word *fluere*, to flow, and signifies any kind of matter which **flows.**

FIG. 12

a *b*



As **liquids** and **gases** may both be poured from one vessel into another, or in other words may be made **to flow,** they are included under the general term **fluids.**

For a class experiment it is interesting to show that it is

true for hydrogen and carbonic acid gases : in the former case the gas **flows upwards**, in the latter **downwards.**

In Fig. 12 are shown two Wooff's bottles, in the one, *a*, we have a small quantity of granulated zinc, to which water and sulphuric acid have been added : in the other, *b*, pieces of broken marble which have been moistened with spirits of salt or hydrochloric acid.

Now observe the way the two delivery pipes are bent to allow the gases to pass off into the cylinders. In *a* we find that it points upwards. This is so, because hydrogen, which is the lightest of all gases, is **flowing** upwards.

In *b* one would imagine that a liquid was about to be drawn off, as the delivery pipe points downwards.

Carbonic acid, being a gas, has the power to expand and occupy a larger space : it thus rises up to the top of the bottle, **flows** over the bent tube into the cylinder, and there displaces the air by reason of its greater weight.

QUESTIONS UPON THE SECOND CHAPTER.

Ques. 1. What is a gas, and what are the qualities of a gas?

Ques. 2. Gases are highly compressible and expansible, but liquids are not. Show that you understand this statement.

Ques. 3. What do you understand by a vacuum? Give an experiment illustrating any result following on the making of a vacuum.

Ques. 4. Vapour, dew, cloud, steam, mist, hail, ice, snow, rain, are all different forms of water. To which state of matter do they respectively belong? Explain the difference between those in the same state.

Ques. 5. How may a gas be converted into a liquid?

Ques. 6. A bladder is filled with air and placed under the receiver of an air-pump: the receiver is then gradually exhausted. What happens, and why?

Ques. 7. Name any *likeness* and any *difference* existing between a *gas* and a *liquid.*

Ques. 8. What happens when a bladder half full of air is put under the receiver of an air-pump?

Ques. 9. Mention an experiment to prove that gas expands when pressure is withdrawn from it.

Ques. 10. Mention a substance that commonly occurs as a solid, a liquid, and a gas. How would you change a solid (1) into a liquid, (2) into a gas.

Ques. 11. Mention two gases, and their properties.

Ques. 12. Give an example of a body existing in three classes of matter.

Ques. 13. Sulphur exists in the three states that matter may exist in. Explain this.

Ques. 14. Is gas a fluid? How can you prove that Hydrogen may be poured upward?

Ques. 15. What do you understand by the *expansibility* of gases?

Ques. 16. Distinguish between an *element* and a *compound.*

Ques. 17. Distinguish between *snow* and *hail.*

Ques. 18. What do you mean by *elements* and *compounds*? Name three of each.

Ques. 19. What is the difference between a *liquid* and a *fluid*?

Ques. 20. Is hydrogen a fluid? If so, state your reasons for thinking so.

CHAPTER III.

SOLIDS.

11. Atoms—12. Molecules—13. Forces of cohesion and adhesion 14. Structure of solids—15. Hardness of solids—16. Alloys.

11. **Atoms.**—This is a word derived from two Greek words signifying something which is so small that it cannot be divided further.

Dr. Dalton, a celebrated chemist, supposed matter to be composed of such very small particles, or **atoms**, that it would be impossible to divide them further, and that these **atoms** are, in the same element, exactly similar in size and weight.

Also, from the assumption that all matter is porous, it is concluded that these **atoms** do not actually touch, but are kept at a certain distance from each other by forces which we shall mention hereafter.

12. **Molecule.**—Having assumed the existence of **atoms,** we shall require a term to denote the smallest cluster which go to form a substance, capable of having a separate existence.

This want is supplied by the use of the term **molecule.**

13. **Forces of Cohesion and Adhesion.**—**Cohesion** is the force which unites two molecules of the same kind; for instance, two molecules of lead or two molecules of water.

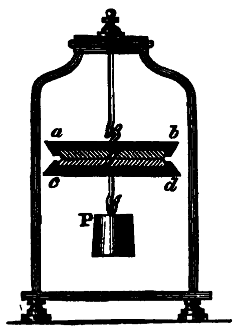
Adhesion is the force that binds two bodies together when their surfaces are placed *in contact.*

If a leaden bullet be carefully cut in halves, so as to form two very smooth surfaces, and the two surfaces be pressed together, then a considerable force will have to be exerted to

separate them; or we might have two smooth pieces of glass *g*, fixed in wooden frames *a b*, *c d*: when pressed together, the upper piece of glass not only supports the lower one, but it has the power of sustaining an additional weight P.

In the sketch (Fig. 13), the plates and weight are shown inside a glass receiver, from which the air has been extracted by means of an air-pump, thus showing that the experiment succeeds as well in a *vacuum* or *empty space*, and therefore must be explained apart from the pressure of the atmosphere; that is, by the **force of adhesion** which acts between the two surfaces.

FIG. 13.



It is well to remember that after all there is *no real difference* between **cohesion** and **adhesion**; the two prefixes *con* and *ad* causing them to be employed when joining molecules of the *same* body, or bodies, with *different* surfaces together.

Again, the **force** of **cohesion** varies in the same solid.

Who has not noticed that a pen-holder may be broken more easily crosswise than along the direction of its length?

This can only be explained by considering the **force** of **cohesion** to be greater along the length of the pen-holder than it is from one side to the other, there being a different arrangement of the molecules in one direction than in the other.

Also, the **force** of **cohesion** is exhibited to a very large extent in some solids, while in others it is scarcely perceptible.

If we take a piece of steel wire and a piece of lead of the same diameter, the former will stand a much greater strain before it breaks than the latter. Why is this?

Simply because the molecules of the steel **cohere** or hold on to one another with a greater force than the molecules of lead.

Liquids, on the other hand, differ among themselves in the amount of **cohesion** they possess.

Take water and mercury as examples. Why can I place my hand to the bottom of a vessel containing *water* with more ease than through an equal quantitity of *mercury* or *quicksilver*? Is it not because the molecules of *quicksilver* are held together

with a greater force than is the case with the drops of water?

The same argument might be pursued when trying to push your hand through a deal board. It is the **force** of **cohesion** which has to be overcome before your hand goes through the wood.

It is very interesting to notice how the **force** of **cohesion** often gives to the drops of a liquid a round shape.

Mercury, spilt on the table, amuses a class when an attempt is made to collect those tiny globules of which it is composed. How quickly these little drops move, and how round is every one of them. The same thing is seen, when water is sprinkled upon a surface coated with lamp-black, the drops of water running about like a number of marbles upon a glass plate.

Another interesting experiment in support of the same truth is performed by introducing into a bottle, containing a mixture of alcohol and water, a small quantity of olive oil (Fig 14).

The two liquids, water and alcohol, not mixing, the oil is seen to float in the form of a globe, partly in the water and partly in the alcohol.

FIG. 14.

This roundness of the drop of oil is another illustration of the **Force of Cohesion.**

Another point to be observed is this, that where **cohesion** is strong in a body, **adhesion** is weak, and *vice versâ.*

Of all liquids, the one which possesses the greatest amount of **cohesion** is mercury, and yet, with but few exceptions, it will adhere to no solid.

I place one finger in water and another in mercury.

Upon taking them out of these liquids what do we observe?

In one case, the water has wetted my finger: not so in the other.

Here then the liquid which has the greatest amount of **cohesion** is sadly deficient in its power to adhere.

It is for this reason that, when using glue, we convert it from a solid to a liquid, in order that it may the more readily adhere to the wood, fill up the little projections upon the broken surfaces, and enable the two surfaces when brought together to touch in a greater number of places.

Similarly, in joining two pieces of earthenware with cement, the **force** of **adhesion** is particularly strong, owing to the liquid cement becoming solid, thereby leaving a greater extent of surface in contact.

Again, two solids do not readily adhere to each other, and yet either or both will adhere to most liquids. Why is this?

When solids are brought together, it is noticed that the **force** of **adhesion** is not sufficiently strong to hold them, their surfaces being so uneven.

Lastly, in *gases*, the **force** of **cohesion** is wanting.

It is, for this reason, that the molecules of a gas are continually trying to move farther and farther away from each other.

To render this last statement clear, if we take two glass cylinders A and B, fill one of them (A) with gas by holding it over an

FIG. 15.

ordinary gas burner, and then bring the open mouth of the other cylinder (B) close to it, we shall quickly perceive that the gas collected in A has found its way into B; for on applying a light to the two cylinders when apart, gas will be observed to burn in each.

14. **Structure of solids.**—What boy is there having a taste for sugar-candy who has not noticed the regular forms taken up by the sugar, as it clings to the thread by which it is suspended; or who has failed to notice the beautiful forms water presents, when ornamenting the window-pane on a winter's morning?

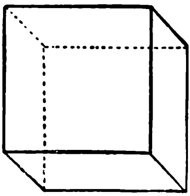
Does this happen by chance? No. Nature has provided that when certain bodies pass slowly from the *liquid* to the *solid* state, their molecules shall not become a confused mass, but that they should take up a definite shape and arrange themselves in a regular order.

Some are seen to take up the form of a *cube*, others that of a *pyramid*, while a third is observed to take to itself the form of a *prism*.

These shapes, viz. *cube*, *pyramid*, and *prism*, have been mentioned here, because in most, if not in every school, models are

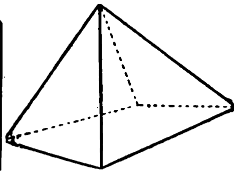
supplied for the purpose of teaching drawing; not that the young reader should think for a moment that Nature confines herself to one of these three forms. Professor Roscoe mentions,

FIG. 16.



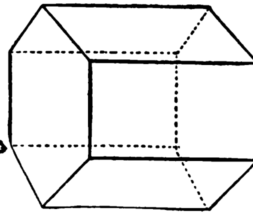
A Cube.

FIG. 17.



A Pyramid.

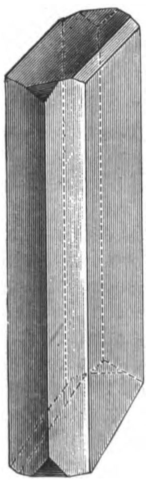
FIG. 18.



A Prism.

in his work on Chemistry, as many as *six systems* of **crystals,** which will include over a thousand known forms.

FIG. 19.



Crystal of sugar.

We have just mentioned the word **crystal.** What does it mean?

As we usually understand the word, **a crystal is a solid, whose molecules have grouped themselves together in such a manner as to present a regular geometrical form.**

In an elementary work, such as this is intended to be, we shall confine ourselves to a few common substances met with in everyday life.

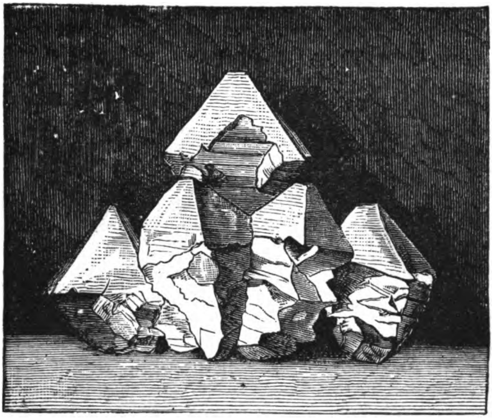
First, take a piece of loaf-sugar.

If we dissolve as much as we can in a test-tube containing warm water, and then pour the liquid into a saucer to cool, very quickly a portion of sugar will be seen adhering to the side of the saucer, having taken up the form shown in Fig. 19. Or, if a piece of alum be powdered up fine and then dissolved in the same way as the sugar, we shall find that when it is allowed to cool a number of bright-shining bodies will separate themselves from the solution and adhere to the side of the glass.

A very good plan is to put a piece of string into the test-

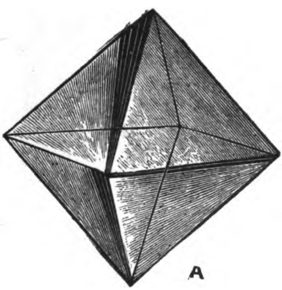
tube or jar (Fig. 22), so that the **crystals** may cling to it, thus enabling them to be removed out of the vessel, without in any way disturbing their shape.

FIG. 20.



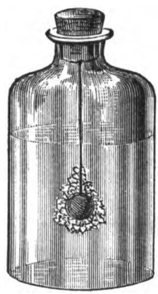
In Fig. 20 is seen a mass of **crystals** of alum obtained in this way, whose exact shape is depicted in Fig. 21.

FIG. 21.



Crystal of alum.

FIG. 22.



Notice how pointed they are, every one of them taking up the form of a pyramid with a square base.

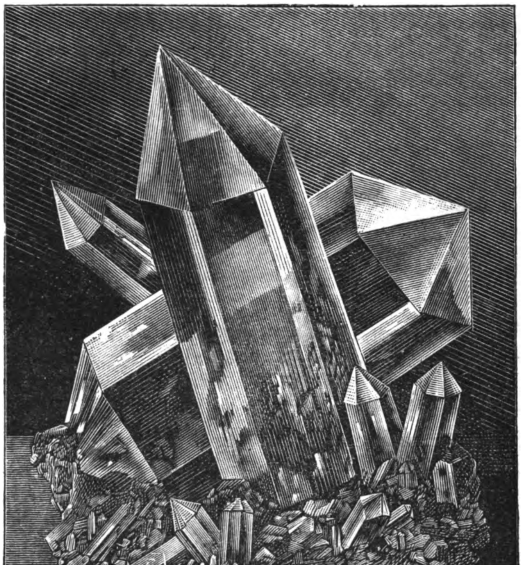
Then again, flakes of snow, when looked at under a micro-

scope, present a splendid illustration of the crystallisation of solids. This was shown in Fig 9, chapter ii.

Boys who are fond of collecting different kinds of rocks will have noticed how well defined is the **crystal** in a piece of quartz, its shape being a combination of a *prism* and *pyramid*.

Fig. 23 will give some idea of the sort of **crystal** met with in a lump of quartz, a *prism* with six sides, capped by a *pyramid* at each end.

FIG. 23.



Then again, ordinary table-salt is a **crystal**.

When slowly deposited from certain brine springs by evaporation, it crystallises in the form of regular cubes.

Lastly, common washing soda crystallises in the form shown in Fig. 25.

There is yet another way of obtaining **crystals**, known as the *dry way*.

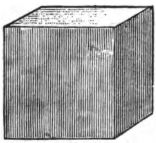
By this we mean that no liquid is employed; we simply

melt the solid and then allow it to cool *slowly*; the vessel containing the liquid thus becomes lined with **crystals**.

Sulphur is perhaps the best illustration of crystallisation performed by the *dry method*.

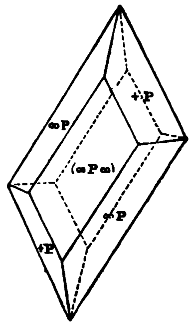
If melted sulphur be allowed to cool *slowly*, it crystallises in long transparent needle-shaped **crystals**, known as *oblique prisms*.

FIG. 24.



Crystal of salt.

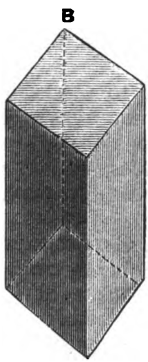
FIG. 25.



Crystal of soda.

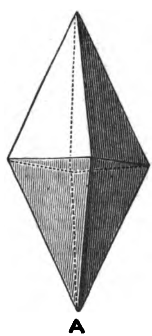
Strange to relate, if these transparent crystals be exposed to the air for a few days, they become opaque, owing to each

FIG. 26.



Transparent crystal of sulphur.

FIG. 27.



Opaque crystal of sulphur.

crystal splitting up into several others of another form, known as the *octahedral* or eight-sided **crystal**.

In Figs. 26 and 27 are seen the two forms sulphur takes, first when the crystal is *transparent*, and secondly when it is *opaque*.

And now comes the question, what advantages are derived from crystallisation?

From what has already been stated, Nature has decreed that bodies, when taking up the form of a **crystal**, require their molecules to dove-tail or fit the one into the other; so that if any dirt be mixed with the solid before it is liquefied, it will then as a matter of necessity be left behind in the liquid. Chemists and sugar-refiners, when they want to obtain a substance absolutely free from any impurity, **crystallise** it, to remove the dirt.

Very often **crystals**, in their formation, become so matted together that their shape is not at all discernible: in which case they are termed **crystalline solids.**

Loaf-sugar, marble, nitre, may be classed under this heading.

Further, it is possible to find solids which do not take up regular forms, but will break or can be split as easily in one direction as in another.

These are called **amorphous** solids, the word **amorphous** being derived from two Greek words: **a** signifying *without*, and **morphé** *shape* or *form*.

Clay, butter, glass, glue, putty, are illustrations of this class.

Then again, in some solids it would appear as if the molecules arranged themselves in straight lines.

As an illustration of this, suppose we take a stick of celery or a piece of rhubarb.

We observe how readily they come to pieces in strips, or threads, or fibres. Hence they are named **fibrous** solids.

Wood, paper, cloth are all illustrations of the same kind.

There is a class of solids very similar, known as **laminar** solids, such as mica and slate, which readily separate in thin layers or laminæ.

We have yet another class of solids, viz. **granular.**

Sandstone, limestone, and the like being supposed to be made up of small rounded **granules** or **little grains**, have given to them the name of **granular** solids.

15. **Hardness of Solids.**—By this we mean the resistance offered by one body to another when being scratched.

For instance, if we are asked which is the hardest of the three solids, *diamond*, *glass*, and *wood*, we at once determine it

by finding out which one is able to scratch the other. Although *glass* may scratch *wood*, it is not able to scratch the *diamond*.

Consequently, on making out a **scale of hardness**, we must write them in the following order, putting the *hardest* first :—

1. Diamond.
2. Glass.
3. Wood.

Again, suppose we are asked to put *iron*, *butter*, *lead*, *wax*, and *diamond* in their **order of hardness**.

Proceeding by the same rule, we know that *iron* is able to mark *lead*, while *lead* would be worn away in trying to mark the *iron*.

Thus *iron* must be looked upon as a harder substance than *lead*.

In the same way we may deal with the rest, until we get the following order :—

1. Diamond.
2. Iron.
3. Lead.
4. Wax.
5. Butter.

In various trades it is very important to know the relative hardness of solids.

In a factory, where *turning*, *drilling*, and *screw-cutting* are performed, it is a matter of great importance in the selection of the tool to bore out a cylinder, to drill a hole, or to cut the thread of a screw.

The tool which answers well for the one may be perfectly useless for the other.

Again, the **hardness** of some solids may be purely artificial, having been rendered so by mechanical contrivances.

Steel and *glass* become hard by suddenly cooling them from a red heat ; in fact, all our saws, knives, chisels, scissors, files, &c., are **tempered** in that way, viz. by raising *steel* to a blood-red heat and then by cooling it with different degrees of rapidity.

In the manufacture of *Bessemer steel* all the carbon and silicon in the cast iron are first burnt out and then a sufficient quantity of cast iron is added to give *carbon* enough to convert the whole mass into *steel*. By which we perceive that it is the introduction of *carbon* that makes the *steel* so hard.

16. **Alloys.**—Another important application of the hardness of solids is seen in the process of **alloying.**

Gold, in its pure state, is soft; but if mixed with a little *copper* it becomes much harder.

As an illustration of this, we have only to look at our *gold coins*, where for every 11 parts by weight of pure gold we find 1 part copper.

Similarly, in our *silver coinage* 92½ parts out of 100 are silver, the remaining 7½ parts being copper; the introduction of the copper making the coin more durable and much harder.

Also in our *bronze money* we have three different metals, copper, tin, and zinc; being mixed in the proportion of 95, 4, and 1.

We might quote many others, but suffice it to say *brass* is an **alloy**, *copper* and *zinc* being mixed in the proportion of 2 to 1; while *pewter* is a compound of *tin* and *lead.*

Printing type is a peculiar alloy, 80 parts out of 100 being *lead*, the remaining 20 parts being *antimony.*

N.B. **Alloys** of metals with **mercury** are termed **amalgams.**

QUESTIONS UPON THE THIRD CHAPTER.

Ques. 1. What is cohesion? Name some substances in which there is,
(*a*) great cohesion;
(*b*) slight cohesion;
(*c*) no cohesion.

Ques. 2. Cohesion is weak in liquids. Explain this.

Ques. 3. Liquids differ among themselves in the amount of cohesion they possess. Show by examples that this is true.

Ques. 4. How would you determine the position of a series of solids with respect to their hardness?

Ques. 5. How would you proceed to obtain crystals? Why do sugar refiners crystallise their sugar?

Ques. 6. What is adhesion? Why do we spread cement over the broken surfaces of two pieces of earthenware we wish to join together?

Ques. 7. The force of cohesion varies in different directions in the same solid. Explain this, and give some examples.

Ques. 8. Describe clearly what you saw in the bottle, stating what you learn from the movement of the drop of ink in the oil. Why is the drop of ink round?

(N.B. The bottle was filled with oil, and a small drop of ink put into it.)

Ques. 9. What is the advantage of *alloying*? Name the component parts of some alloys.

Ques. 10. What do you understand by *molecules* and *atoms*?

Ques. 11. Why will a liquid adhere to a soiid more readily than two solids to each other?

Illustrate this by example, and show that *adhesion* is greater than *cohesion* in the instance selected.

Ques. 12. Distinguish between *cohesion* and *adhesion*.

Ques. 13. In using glue, what advantage arises from turning it into a liquid?

Ques. 14. What are *crystalline* bodies? Name some, and say how crystals are formed.

Ques. 15. Gases have no cohesion. Explain this.

Ques. 16. What is a *crystal*? What common substances form crystals?

Ques. 17. How do you tell which is the hardest of two things? Put *iron*, *butter*, *lead*, *wax*, and *diamond* in their order of hardness.

Ques. 18. A boy dips one finger into water and another into mercury. What difference does he observe on taking his finger out, and how do you explain it?

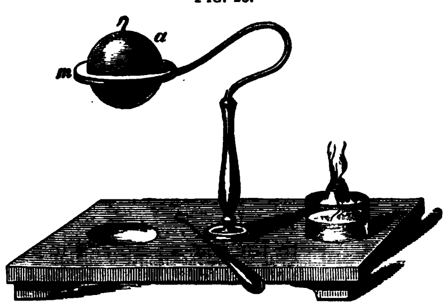
CHAPTER IV.

EFFECTS OF HEAT UPON SOLIDS.

17. Solids expand under the influence of heat—18. Practical applications—19. Exceptions to the above rule—20. Heat diminishes the cohesion of solids—21. Heat liquefies solids—22. Difference between melting and dissolving.

17. **Solids expand under the influence of heat.**—We shall endeavour throughout this chapter to inquire what are the effects of heat upon *solid* bodies.

FIG. 28.



First, we observe that under its influence bodies **tend to expand,** or, in other words, to **occupy more space.**

A simple experiment will render this clear.

Suppose we take a brass ball which will just pass through a metallic ring, and heat it either by the aid of a spirit-lamp or by placing

it into a saucepan of boiling water. We then notice that the ball no longer passes through the ring. Why is this?

Its volume has increased, the molecules of brass having moved farther apart. On the other hand, if the ball be cooled by immersion in cold water, then it returns to its former size, showing that the opposite effect is also true, viz. that bodies **contract** or **get smaller** by reason of **cold.**

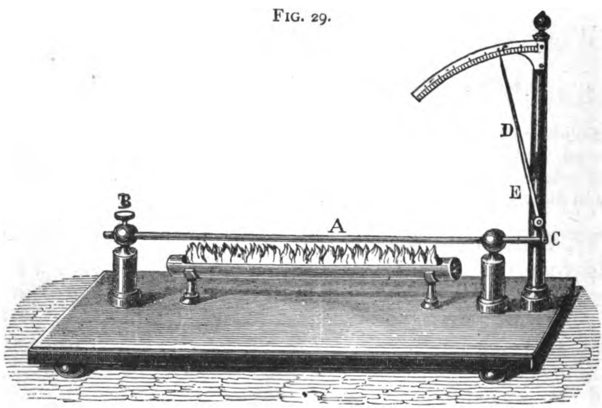
In Fig. 28 is shown the piece of apparatus often employed to demonstrate the two effects just mentioned.

It is known as *Gravesande's Ball and Ring*, the letter *a* denoting the *ball* and *m* the ring.

Another experiment showing the **expansion** of solids by heat is performed in the following manner :—

A metal rod A (Fig. 29), either brass, copper, or iron, is

FIG. 29.



fastened at one end B by means of a thumb-screw, while the other end is free to slide through a hole in the upright support E. At C the end of the rod presses against a little finger D, which registers upon a graduated arc the amount of expansion for each metal.

Underneath the bar A stands a metallic trough, into which methylated spirit is poured.

As soon as the spirit is ignited the flame plays around the bar, causing **it to expand**; but being fastened at B it is only free to move in the direction A C; and while so doing it

presses against one end of the finger D, thereby registering the amount of expansion upon the index for the metal selected.

It is very important to notice that a different result is obtained when another metal is heated.

For instance, *brass* **expands** more than *iron* or *steel*, while *copper* **expands** less than *zinc*.

If the young reader would like to test this, he has only to take the strips of two different metals of the same length, say *brass* and *zinc*, and rivet the two ends together.

FIG. 30.

Upon heating the compound bar it no longer remains straight; for one of the metals **expanding** more than the other causes it to have a *curved* appearance.

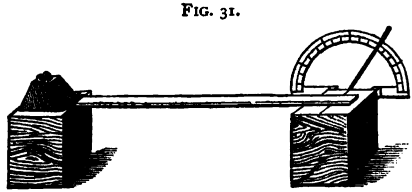
In the sketch (Fig. 30) *zinc* is observed to have expanded more than the *brass* with the same amount of heat; and since the ends are riveted together, the *unequal* expansion of the metals compels one of them to have a curved appearance while the other remains straight.

Another interesting experiment illustrative of the **expansion** of solids is related by Mr. Wright in his work on 'Sound, Light, and Heat.'

Upon two hard blocks of wood (Fig. 31) a rod of iron of any length is placed. One end is secured by placing a heavy weight upon it.

Under the other end of the rod a fine sewing-needle is placed.

FIG. 31.



Through the eye of the needle passes a straw about six inches long, secured with sealing wax.

If now we take a piece of cardboard and divide it as in the figure, seeing that it is placed vertically by the side of the block, and that the straw is vertical before the experiment begins, we

shall observe a consequent rolling of the needle produced by the expansion of the rod.

This causes the straw to move *to the right*; when, however, the source of heat is removed, the rod **contracts,** giving motion to the needle in the opposite direction. This is indicated by the straw turning to the left.

The other statement is equally true, viz., **solids contract** when heat is abstracted from them.

To show this we employ a strong cast-iron frame (Fig. 32)

FIG. 32.

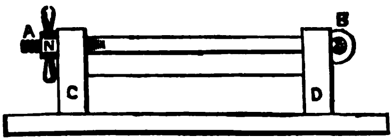
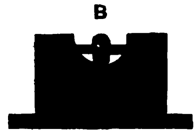


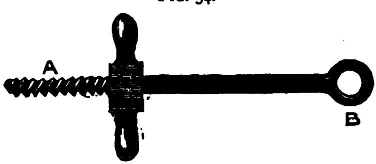
FIG. 33.



End view, showing the cast-iron pin passing through the eye B and resting against the shoulder D.

with two uprights, C and D, made so as to receive an iron bar A B. The bar A B, Fig. 34, has at one end an eye B, while on the other end the thread of a screw is cut to allow a nut N to work freely along the bar.

FIG. 34.



When the bar has been heated to redness, it is taken out and placed in the position shown in Fig. 33, with a cast-iron pin through the eye B; at the same time the nut N is screwed up tightly against the shoulder C.

Now what happens is this.

As the iron bar cools down it shrinks or **contracts** to such an extent that the pin placed through the eye B and across the shoulder D is broken, thus showing how great is the force with which a solid contracts.

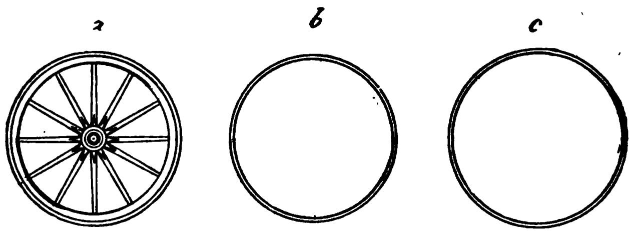
18. **Practical applications.**—The principle upon which solids **expand** and **contract** is so often used in the various handicrafts that we propose to devote a little space to the consideration of them.

First, let us consider how a wheelwright binds the spokes and rim of a wheel together (Fig 35, *a*)

The *tire* (*b*) when cold is too small to pass over the *rim*; but as soon as the *tire* has been heated its diameter is so much increased that it falls over the *rim* quite easily. This is shown in the figure at (*c*).

Cold water is then thrown over the whole, thereby causing a rapid **contraction** of the *iron-hoop* or *tire*, which has the effect of binding the *spokes* and *rim* firmly together. Again,

FIG. 35.



Wheel and tire. Tire before it is heated. Tire when red hot.

walls which have bulged out have been brought back again to their vertical position by means of the **expansion** and **contraction** of iron bars.

Notably was this the case in the Conservatoire des Arts et Métiers in Paris.

In this building, which was formerly a convent, the nave of the church was converted into a museum for industrial products, machines, and implements.

In its arch, traversing its length, appeared a crack, which gradually increased to the width of several inches, permitting the passage of rain and snow.

The opening could easily have been closed by stone and lime, but the yielding of the side walls would not have been prevented by the adoption of these means.

The whole building was on the point of being pulled down when a natural philosopher proposed the following plan, by which the object was accomplished.

A number of strong iron rods were firmly fixed at one end to a side wall of the nave, and after passing through the opposite wall they were provided on the outside with large nuts,

which were screwed up tightly to the wall. By applying burning straw to the rods they expanded in length. The nuts by this extension being now removed several inches from the wall, were again screwed tightly to it.

The rods on cooling **contracted** with enormous force and made the walls approach each other.

By repeating the operation several times the crack entirely disappeared.

FIG. 36.

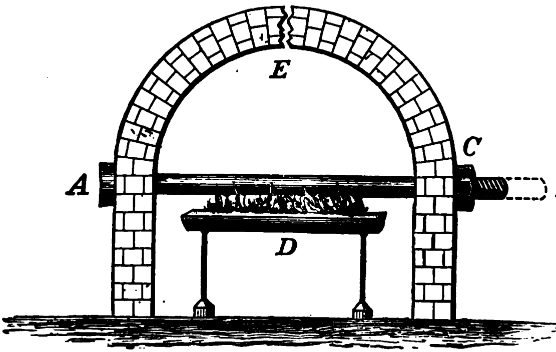
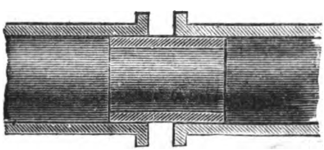


Fig. 36 shows the plan adopted. A B represents one of the rods passing through two opposite walls.

C is the nut employed to tighten the bar as it **expands** under the influence of heat supplied to it at D.

At E is shown the crack at the top of the arch.

FIG. 37.



Telescopic water-pipes.

The dotted line shows the extension of the bar when heated.

Now, it is easily seen that if the source of heat be removed

the bar will endeavour to go back to its original length, which, in so doing, will draw the walls together.

Again, in fitting up a large building with hot-water pipes, allowance has to be made **for the expansion** of the iron piping when hot water is passing through them.

This is done by making the pipes to slide one within the other (Fig. 37), after the manner of the joints of a *telescope.*

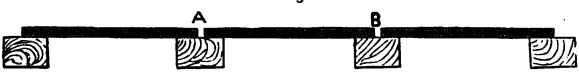
Iron beams, employed in buildings, must have their ends free to move forward, otherwise the opposite walls would be thrown out of the perpendicular.

In roofing, the sheets of *zinc* and *lead* are so arranged that they are able to overlap each other during **expansion.**

Then again, in laying down tramway lines and lines of rail the **expansion** of the metals has to be considered.

In a railway it is not usual to allow the ends of the rails to

FIG. 38.



Railway lines resting upon blocks or sleepers.

touch each other, a small interval (Fig. 38) being left between them to make room for any alteration of length.

Just to take one instance, viz. the length of railway from London to Edinburgh, which is about four hundred miles. The extreme variations of temperature would produce difference in the length amounting to 1,288 feet.

Just try and realise what this means.

If the rails formed a continuous line when first put down the very next approach of warm weather would cause the rails to become *curved* or they would be broken to pieces.

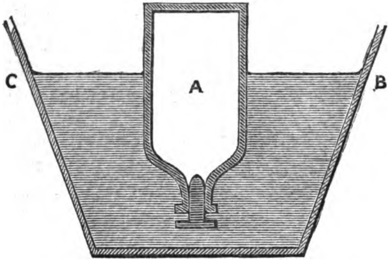
Further, *glaziers* ought to know something about the **expansion** of glass.

If the window pane be fitted into the frame too tightly during the winter months, it would be no very great wonder if it were to crack when exposed to the great heat of summer.

Another important application of this principle is seen when a glass stopper is removed from the neck of a bottle in which it has become too firmly set. By plunging the neck into boiling water (Fig. 39) the neck **expands** first, and thus the stopper is freed from its hold.

The stopper of a *decanter* being too firmly fixed, it is not unusual to wrap a cloth steeped in hot water around the neck, thereby causing the neck **to expand** and thus to release the stopper.

FIG. 39.



Again, the same principle explains many too well-known occurrences.

Hot water when poured very suddenly into a *cold glass* causes it **to crack.** This arises from the **unequal expansion** of the glass, the heat of the water not having had time to extend its influence to other parts of the glass vessel.

On the other hand, the same accident occurs when *cold water* is poured into a *warm* glass vessel: here **sudden contraction** takes place where the *cold water* comes in contact with the *warm glass.*

Watch and clockmakers too are concerned with the **expansion** of the various metals used in their handicrafts.

The pendulum, we know fully well, is the regulator of the motion of a clock. Suppose the clock to keep correct time when the weather is very cold; then with a rise of temperature the length of the pendulum will increase, thereby causing a slower movement, and thus the clock will lose.

Of course the opposite effect would be produced if the temperature of the air were to fall; the length of the pendulum would be less, and consequently a more rapid beat would be made by the pendulum. Thus we see clocks are liable to go too fast *in winter* and to lose time *in summer.*

Some method has therefore to be adopted whereby the 'bob' of the pendulum shall at all times be at the same distance from the point of suspension, if correct time is to be obtained.

Furnace-men are cautioned against fitting the *bars* of *furnaces* too tightly in their places, lest while **expanding** they might exert such force that the *bridges* or *brickwork* at the back of the furnaces would be thrown down.

Lastly, railway-engineers see that iron bridges are never

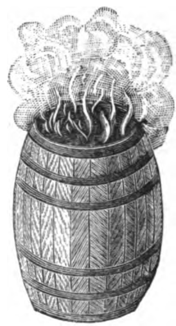
fixed at both ends: one end, as a rule, rests upon rollers to allow for the **expansion** of the bridge during the hot weather.

19. **Exceptions to the above Rule.**—There is an old saying, and a very true one, which is, 'Every rule has its exception.'

Although we have been quoting instances where solids **expand** by **heat** and **contract** by **cold**, we have not far to look to find *exceptions.*

A piece of stretched india-rubber on being heated **contracts**; iodide of silver **contracts** with a rise of temperature; bodies which absorb moisture, such as wood, paper, clay, &c., undergo a **contraction** when they are heated.

FIG. 40.



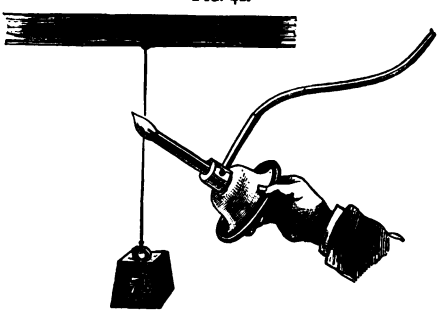
A moist sheet of paper, placed before the fire, coils up on the side which is warmed.

Coopers light a fire inside a barrel (Fig. 40) in order that they may *curve* the *staves*, the heat from the fire having the effect of **contracting** the part exposed to it.

20. **Heat diminishes the cohesion of solids.**—In the last chapter a great deal was said about the **force** of **cohesion** and the way it differed in different solids.

We have now to consider how it may be *increased* or *diminished* in one and the same solid.

FIG. 41.



A piece of iron wire (Fig. 41) is fastened to a beam at one end and supports a weight of 7 lbs. at the other end.

We observe no sign whatever of the wire breaking.

The **force** of **cohesion** among the particles of the wire is quite sufficient to bear a strain of 7 lbs.

But suppose we bring the flame of a Bunsen burner to play around the wire for a few seconds; then a crash is heard: the 7 lb. weight has fallen to the floor. Why?

Where the wire was heated the **force of cohesion was diminished**, and not being equal to a 7 lb. strain the wire parted, and thus allowed the weight to fall.

It must not be understood that we are obliged to use a 7 lb. weight, for a weight of 4 lbs. would do just as well, the only difference being that more heat would have to be given to the wire before it would break.

We might have used copper wire, about the thickness of a stout sewing needle.

It will support a weight of at least 28 lbs.

As soon as the flame is brought near the wire the weight drops. The atoms of copper are no longer able to resist the pull to which they are subjected. The modern explanation is, that the particles of copper are set into such a violent state of trembling by the heat of the flame that their power of holding together has been almost entirely taken away.[1]

Again, a *blacksmith* wants to cut a piece of bar iron asunder. Does he do it while the iron is cold? No.

He places it in the forge, heats it to redness, or even to a white heat, brings it out upon the anvil, and with the greatest ease cuts it asunder. This is due to the **force of cohesion** having been considerably **diminished** by the application of heat.

A very important application of this is seen in the process of **welding**.

A boy takes his broken hoop to the smith to be mended. Both ends are placed in the fire and raised to a white heat, and while in this soft condition the smith is able to hammer or **weld** the two ends firmly together.

Another very good illustration was once given by a boy attending the classes. He was asked how he could prove experimentally that heat **lessens** the **cohesion** of solids.

In reply, he stated that if potatoes were placed into a saucepan of boiling water and allowed to remain on the fire for about twenty minutes, upon taking them out they would fall to pieces like a ball of flour.

The potatoes, which could be thrown about when cold, could scarcely bear the prong of a fork when hot, showing that the **force of cohesion** among the various parts of the potato had been sensibly **diminished**.

[1] Goodeve's *Mechanics*, p. 14.

Boiler-makers, in fastening two plates of iron together, put the *rivets* in while they are red hot. The advantage in so doing is quite clear. In heating the rivets the **force of cohesion** is **lessened** to such an extent that hammering can more easily be performed.

21. **Heat liquefies Solids.**—Not only does heat cause a solid to **expand** and to **diminish** the amount of its **cohesion**, but, if sufficient time be given to it, heat will change its condition from *solid* to that of *liquid*.

Now this is very important to *metal-workers* and to those employed in *smelting*.

We know that ice melts with the heat of an ordinary room, lard with the heat of a common fire, but more heat than could be obtained from these sources would be required if we wanted to obtain iron from its native ore.

The metal **most easily liquefied** is *mercury* or *quicksilver*.

In fact, in this climate of ours we never see it in any other state than that of a liquid; but if mercury were exposed to an Arctic winter, where the temperature falls many degrees below the freezing-point, it would become solid, and could then be cut like a lump of lead.

It is interesting to note at what temperature many solids **fuse** or **melt**.

Starting with *ice*, the next in order that will melt is *butter*, which *liquefies* at 33° [1] above the freezing-point.

Then come *wax*, *tin*, *lead*, *zinc*, *silver*, *gold*, and *iron*, the last of which requires as much as 1,500° of heat to melt it.

This is not all; *platinum* will not melt in any fire or furnace, but requires the greatest possible heat, such as *electricity* alone can give.

Silversmiths and *goldsmiths* take advantage of this in using *platinum* crucibles for melting silver and gold.

There is one substance which up to the present has resisted all attempts that have been made to melt it, and that is *carbon*.

Ganot tells us that a celebrated French chemist has succeeded in softening *carbon*, so that it was flexible, which is a condition next to that of fusion.

In speaking of the manufacture of glass, a very curious experiment is often performed with *Prince Rupert's drops*.

[1] In Chap. X. we shall say more definitely what is meant by a *degree*.

These are simply drops of molten glass which have been allowed to fall into a bucket of water.

They are somewhat pear-shaped in form, their ends being so hard that they can scarcely be broken on an anvil; but if scratched with the point of a pin the whole would fly into powder. Another important application of the fusion of solids by heat is witnessed in the manufacture of British plate glass, when it is the custom to blow a cylinder of glass, to cut it open, and to spread it out.

To make it even, the glass is blown in a wooden mould, the sides of which are wetted with water; the red-hot glass converts this into steam, which keeps the glass from burning the wood.

Lastly, the quantity of heat required to melt ice may be comprehended from a calculation by Faraday, who found that to melt a cubic yard of ice the heat given out by the burning of a bushel of coals would be required; later still a French chemist said that if the globe were covered with a layer of ice 104 feet thick it would require the heat of the sun's rays for a whole year to melt it.

22. **Difference between Melting and Dissolving.**—A body is said to **dissolve** when it is converted into a liquid by virtue of an attraction between its molecules and those of a liquid.

Sugar, *salt*, and most *salts* are **liquefied** in this way.

Melting is the passage of a solid body to the liquid state by the action of heat alone.

Thus we see that it is essential for a liquid to be present for a substance to **dissolve.**

Camphor acts rather strangely when heated, by passing direct from the *solid state* to the form of a *vapour*; so also does *iodine.*

QUESTIONS UPON THE FOURTH CHAPTER.

Ques. 1. If workmen constructing a railway place the ends of the rails closely together, what happens, and why?

Ques. 2. Why does the blacksmith put the tire on a wheel when red hot?

Ques. 3. What is the effect of heat upon solids? Explain the cracking of a glass when hot water is poured into it.

Ques. 4. Give examples of the use of the terms *cohesion* and *adhesion.* What effect has heat upon the cohesion of solids?

Ques. 5. If hot water be poured into a cold glass the glass will probably crack. Account for this.

Ques. 6. If *iron*, *water*, *lead*, *mercury*, *butter*, and *tin* be made so cold that they are all solid, and then heated, what will be the order in which they will melt?

Ques. 7. Heat lessens the cohesion of solids. Explain this.

Ques. 8. It is often difficult to remove a glass stopper from a bottle, but if the neck be plunged into hot water the difficulty is lessened. Why is this so?

Ques. 9. How does heat generally affect the size of bodies? Are there any exceptions to the general rule?

Ques. 10. A rod of brass just fits between two supports; ice-cold water is poured over it and the bar falls. Why is this? The bar is now heated in a boiler and is found to be too long. Why?

Ques. 11. I place potatoes into a saucepan containing boiling water and there leave them. On taking them out, they fall to pieces like a ball of flour. Account for this.

Ques. 12. A square of glass is fitted tightly into a frame during the winter months. In the summer the glass suddenly cracks. Account for this.

Ques. 13. Water-pipes are fitted with telescopic joints. Why?

Ques. 14. The bars of furnaces must *not* be too rigidly fitted at their extremities. Why is this so?

Ques. 15. What is the difference between *melting* and *dissolving*? Give an example of each.

Ques. 16. Sketch and describe Gravesande's ball and ring.

Ques. 17. Sketch and describe Ferguson's pyrometer.

Ques. 18. How are tires fitted tightly to wheels?

CHAPTER V.

MEASUREMENT OF MATTER.

23. **Ancient Modes of Measuring.**—The use of weights and measures must have been one of the earliest necessities of civilised life. Josephus, the Jewish historian, mentions the tradition that Cain, after his wanderings, built a city called Nod and settled there; also that he was the author of weights and measures.

The extreme antiquity of the use of weights and measures is likewise shown by the fact of the ancient heathens attributing

the origin of them to their gods—the Egyptians to the god *Thoth*, and the Greeks to *Mercury*.

The most ancient unit of length in Egypt under the Pharaohs was the **natural** or **common cubit** of six palms, and equal to about 18·24 English inches, while there is no satisfactory evidence to show that *this ancient unit* had any reference to the dimensions of the earth, but that the **cubit** as well as the **foot** were taken from the proportions of the human body.

Further, we learn from ancient manuscripts that the **cubit** was the length of a man's arm, measured from the point of the elbow to the extremity of the middle finger, it being considered as the most convenient **standard unit of length.**

Mr. Chisholm, in his work entitled 'Science of Weighing,' gives us the following table, by which a relation can be established between the different measures of length:—

He starts with **the digit** or breadth of the middle part of the first joint of the forefinger, and calls it **the unit.** Then,

The digit being equal to 1 part,		
The palm or **handbreadth** will be equal to 4 parts,		
The span	12	„
The foot	16	„
The cubit	24	„
The step or **single pace**	40	„
The double pace	80	„
The fathom, or length of extended arms from the tips of the fingers, nearly equal to the height of a man	96	„

Again, **the cubit** is the only measure of length we meet with in the Book of Genesis, as being in existence before the Flood. Sir Isaac Newton, when speaking upon the subject of **cubits**, said that he believed the **sacred cubit** among the Jews was equivalent to 24·7 of our inches.

If, however, we take the **natural cubit**, or **cubit** of a man, mentioned in Deuteronomy, to be equal to 18·24 of our inches, then the size of the iron bed of the giant Og, King of Bashan, stated to be 9 cubits long and 4 cubits broad, must have been 13½ feet by 6 feet.

According to the ancient reckoning, that a bed was usually one-third longer than the height of a man, Og must have been 9 feet high; and the height of the giant Goliath of Gath, stated

in the First Book of Samuel to be 6 cubits and a span, must have been 9 feet 4 inches.

Again, the **Greek foot**, which was two-thirds of the **Egyptian cubit**, or 12·16 English inches, having been introduced into Italy as a mode of measuring, it was there divided into 12 parts, or *unciæ*, by which each unit of measure or weight, termed *as*, was divided into 12 *unciæ*. It is from this Latin word *uncia* we derive our English words **inch** and **ounce**.

Thus we trace the modern measure of **foot** with its division of 12 **inches** back to the **Greek foot**.

Similarly, the French **foot** is supposed to have been the length of Charlemagne's foot, while the English **yard** has been said to have been derived from the length of the arm of Henry I.

Another writer supposes the **yard** to have been handed down from **the yard** or **gird** of the Saxon kings kept at Winchester.

King Edgar is recorded to have decreed, with the consent of his *wites*, or *council*, that 'the measure of Winchester shall be the standard.'

The **yard** and the **ell** were originally identical measures in England.

From the period of the Conquest down to the time of Richard II. the statutes and official documents were either in Latin or in Norman French, and the **yard** and the **ell** are employed to indicate the same unit of length.

The existing **imperial yard** is so nearly identical in length with these old **standard yards** of Henry VII. and Elizabeth that it scarcely exceeds them by one-hundredth part of an inch.

The **double cubit** is also mentioned as a measure of length.

An old Egyptian **double cubit** found in the ruins of Karnac can be seen in the British Museum.

We also read of a measure very nearly equal to two cubits in use among the Romans under the name of **ulna**, or **ell**.

The **ulna** is mentioned by Pliny, when describing the measurements of the girth of a tree, as half the length of the extended arms of a man.

In these days the distance between the outstretched arms of a man we term a **fathom**.

It may thus be fairly assumed that the measure of a **double cubit** or 3 feet, under the name of **ell** or **yard**, came into use in olden times as a very convenient measuring unit, and found its way into England as the **standard unit** of **length**.

We have one other unit which reminds us of former tim

which is the **hand.** Jockeys and horse-dealers speak of a horse as standing so many **hands** high, the **hand** being equal to 4 English inches.

24. **Measurement of Length.**—Now let us turn our attention to the *modern* way of measuring **length.**

At the present time our **standard unit** is **the yard,** from which all other measures are taken.

Thus **a foot** is a third of **the imperial yard; an inch** is the thirty-sixth part of a yard; a mile contains 1,760 imperial yards.

To prevent any dispute about the exact length of this measure, the Government has decreed that the measure of a yard shall be the *distance* between two fine lines marked upon a bronze bar, which has been made of copper 16 parts, tin 2 parts, and zinc 1 part.

The shape of the bar is shown in Fig. 42, its total length being 38 inches, breadth 1 inch, and depth 1 inch.

FIG. 42.

Likewise we observe that the length or distance between these fine lines must be taken at one particular temperature, viz. 62° Fahrenheit, since, as we have already pointed out, the bar is liable to expand under the influence of heat, and contract by reason of cold.

For the information of any who may wish to see the **imperial yard,** it may be mentioned that it is deposited in the Houses of Parliament, Westminster, and correct copies of it at the Court of Exchequer, the Royal Mint, the Royal Society, and the Royal Observatory at Greenwich.

In France the *standard measure* of length is the **mètre,** which is founded on the measurement of the earth from the pole to the equator on the meridian of Paris. This distance is divided into 10,000,000 equal parts, one of which parts is taken as the *unit of length,* and called a **mètre,** from the Greek *metron,* a measure.

Boys studying geography will find it of great service if they examine a globe, and thus become familiar with the way the French derive *their standard of length.*

25. **Measurement of Area.**—By this we mean the measurement of the **surface** of a body.

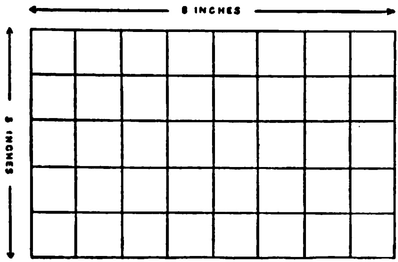
A book if measured along one edge will give a length of 8 inches, but if measured along an *adjacent* edge only 5 inches. What amount of **surface** is there on the outside of one cover?

The usual plan in this case is to divide the cover into a number of equal squares by drawing lines parallel to the sides, at a distance of 1 inch apart, and then to express the **surface** as containing so many of these squares.

Thus in the case selected, Fig. 43, the **surface** contains 40 squares, each measuring 1 inch by 1 inch.

We therefore say the **area** is 40 square inches.

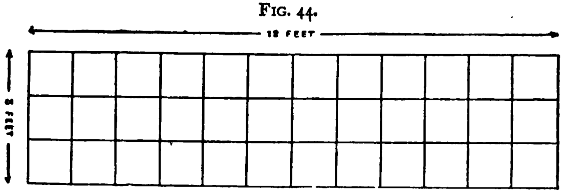
FIG. 43.



Similarly, if a piece of wood in the shape of a rectangle be given, Fig. 44, whose length is 12 feet and breadth 3 feet, **its area** of 36 square feet can be seen by drawing lines parallel to the sides, each 1 foot apart.

From these two illustrations we can obtain a very simple rule for calculating the **area** of any rectangular surface. Multiply the **length** by the **breadth**, and the **product** thus obtained will give the **area** required. This, of course, presupposes that the dimensions are both of the same name either both in **feet** or both in **inches.**

FIG. 44.



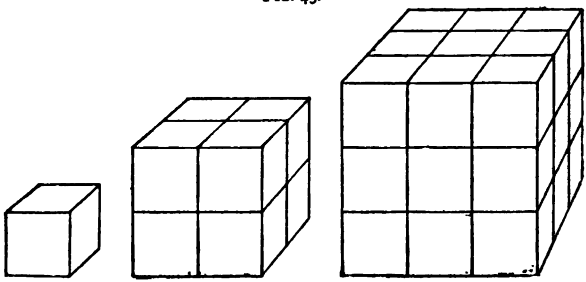
A very good plan, for the purpose of bringing this home to a class is to pass a box round, asking each boy to obtain his own dimensions, and thereby ascertain the total **area** of the six surfaces.

26. **Measurement of Volume.**—By the word **volume** we

usually understand the amount of room a body takes up, and it is measured by the number of *cubes* that can be stowed away in any given space.

Perhaps the best method of dealing with the question of **volume** is to select a number of little cubes or dice, Fig. 45, each

FIG. 45.

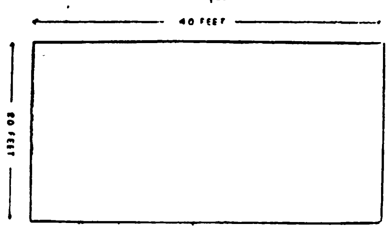


measuring 1 inch along the edge, and then to place them in groups of 8 and 27.

If the edges of each group be measured, we shall obtain in the first case 2 inches for the length of one edge and 3 inches for the length of the other.

To take one numerical example, which every schoolboy should know how to work. What number of cubic feet of air are there in a room which measures 40 feet long, 20 feet broad, and 15 feet high?

FIG. 46.



This question resolves itself into finding how many cubes, each measuring 1 foot along its edge, can be stowed away side by side to fill up the entire space within the room.

We proceed upon the same lines as before.

It is quite evident that there will be 800 **square feet** in the floor, Fig. 46; so that 800 cubes with faces each of 1 square foot in area can be placed side by side with each other.

Then comes the question, how many tiers or rows can be

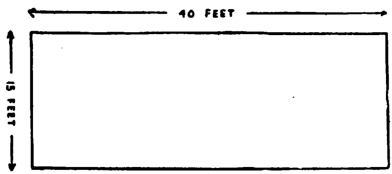
arranged one over the other to make a total height of 15 feet?

With very little calculation we perceive the number to be 15 (Fig. 47).

Hence the total number of cubes required will be $800 \times 15 = 12{,}000$.

Thus we obtain the following rule for finding the **volume** of a **rectangular** solid. Multiply the **length, breadth,** and **thickness** together; the result will give the **volume** in cubic measure, either in cubic inches, in cubic feet, or in cubic yards, according to the unit of measurement adopted.

FIG. 47.

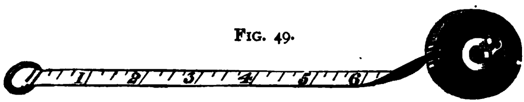


27. **Apparatus required for measuring Length.**—These consist of the *two-foot rule*, the *tape measure*, the *compasses*, the *callipers*, the *wire-gauge*.

FIG. 48.

Two-foot rule.

FIG. 49.



Tape measure.

The *first* of these five measures, viz. the *two-foot rule*, we find of great service when we want to ascertain the *length*, *breadth*, or *thickness* of any rectangular solid; as, for example, the dimensions of a box or the area of a plank.

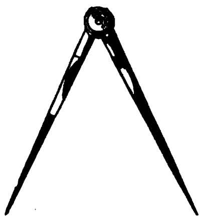
The *second* or *tape measure* is frequently employed by tailors, masons, and architects, where a *two-foot rule* would be found inconvenient.

Also in finding the circumference of any round body a *tape measure* is very handy.

The *compasses* a carpenter employs when setting off fixed distances along a piece of timber; as also a schoolboy when dividing a line into a number of equal parts.

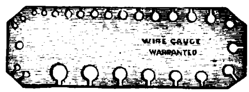
The *callipers* resemble somewhat a pair of compasses in that it may be used for the purpose of finding the internal and external diameter of a cylindrical body.

FIG. 50



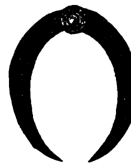
Compasses.

FIG. 51.



Wire-gauge.

FIG. 52.



Callipers.

For convenience, however, the legs are curved, as shown in Fig. 52.

The last of the five, viz. the *wire-gauge*, is a piece of flat steel, cut, as in Fig. 51, with a number of slots of different widths.

These widths being all known, the diameter of wires which just pass through them can be at once inferred.

Among *metal-workers* this gauge is often called into requisition, the wires being known under some number, either No. 1 or No. 26, according to the slot on the gauge through which the wire passes.

In the Birmingham wire-gauge (B.W.G.) the smallest wire that can be measured is numbered 26, while the wire of greatest diameter is numbered 1.

QUESTIONS UPON THE FIFTH CHAPTER.

Ques. 1. What do you understand by 'magnitude'? Explain the terms *line*, *surface*, and *volume*.

Ques. 2. What is understood by *volume* and *area*?

Ques. 3. What are callipers? How are they used?

Ques. 4. What measurements would you make to calculate the area of the top of a table?

Ques. 5. What do you mean by the *volume* of a box? What is the volume of a box which is 3 feet long, 2 feet wide, and 12 inches deep?

Ques. 6. Measure the box given you, and find its *surface* and *cubical content*. (An ordinary card-board box to be passed round the class.)

Ques. 7. Mention as many instruments as you can for measuring length.

Ques. 8. What is the area of a wall which measures 17 feet 9 inches long and 13 feet 10 inches high?

Ques. 9. Name parts of the body that have been used for measurements. How are bodies measured by cubes?

Ques. 10. Why is it necessary to refer to the temperature of a body in selecting it as the standard of length?

Ques. 11. Give the measurement roughly of the book passed round, and state the *surface* of one of its covers, and its *cubical* content.

Ques. 12. What were the following ancient measures of length: *cubit*, *span*, *fathom*, *palm*, and *hand*?

Ques. 13. State what you know of the introduction of the *yard* into the English table of measurements.

Ques. 14. What would be the cost of digging a moat 50 feet long, 30 feet broad, and 15 feet deep, at 9*d.* per cubic foot?

Ques. 15. What is the difference between an 8-inch cube and 8 cubic inches?

Ques. 16. Which is the larger board, one having a surface of 16 square inches or one which is 16 inches square? By how much is the one larger than the other?

Ques. 17. State what you know of the imperial standard measure of length.

Ques. 18. What are the advantages and disadvantages in the use of the tape-measure as a measure of length?

Ques. 19. Suppose a carriage wheel to have a circumference of 22 feet, how often will it revolve in passing over a distance of 22 miles?

Ques. 20. What would be the cost of covering a flat surface, 12 feet long, 8 feet broad, with gold-leaf, at 1*d.* per square inch?

Ques. 21. Find the cost of papering a room 14 feet long, 12 feet wide, 10 feet high, with paper 27 inches broad, at 2*s.* per piece of 12 yards.

CHAPTER VI.

LIQUIDS.

28. *Viscous* and *mobile* liquids—29. Surface of liquids—30. Pressure of liquids—31. Capillary phenomena of liquids—32. Effects due to capillarity.

28. **Viscous and mobile liquids.**—In commencing this chapter, we have to consider the *second* form in which **matter** presents itself.

Hitherto we have been dealing with **matter** in the **solid** state; now we want to talk about **matter** in the **liquid** condition.

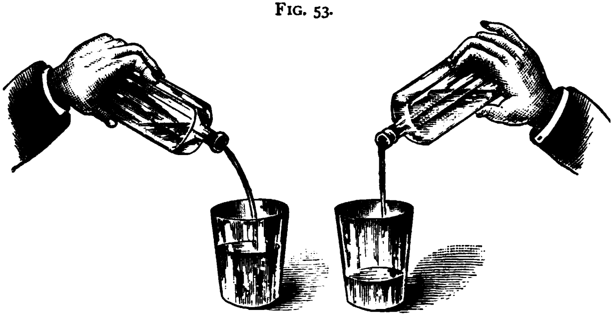
How many different kinds of liquids are there? That all depends upon the way in which you propose to class ther

One person might divide them in one way, and another person quite differently.

Scientists agree to class liquids according to *their rates* of *movement*: for instance, if a liquid *moves fast*, they would call it **mobile**; or if it moves slowly, a **viscous liquid.**

To illustrate our meaning let us take two bottles (Fig. 53)

FIG. 53.



of the same size, containing *alcohol* and *glycerine* respectively, and pour their contents into two glasses. Which of the two would empty itself first?

Undoubtedly, the *alcohol.* Why?

The *molecules* of *alcohol* roll one over the other much more quickly than the *molecules* of *glycerine* do. Hence the *alcohol* is the first to run out, for which reason it is termed a **mobile** liquid.

Again, suppose we take *castor-oil* and compare its running powers with that of *water.* It will not take long for us to see that *castor-oil* is the **viscous** and that *water* is the **mobile** liquid.

29. **Surface of liquids.**—In the next place let us examine the surfaces of liquids, and see whether they are not similar to those made by the use of the **plane.**

We want now to apply this word to the *surfaces* of liquids in a state of rest. First, we observe that the *free surface* of any liquid is **horizontal**, that is, perpendicular to a plumb-line held above it. Now, this must be accepted in a limited sense only; for anyone at all acquainted with the sea will have noticed that the masts of a ship become visible before the hull, which would not be the case if the *surface* of the ocean were perfectly **horizontal.** In Fig. 54 we have depicted a ship as seen when

at different distances from the land. To the right of the picture the sails alone are visible, whereas to the left a full-rigged ship is presented to our view.

FIG. 54.

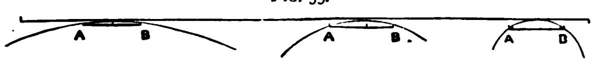
We must, therefore, modify the statement made above, for liquids at rest present *two* surfaces, **plane** and **curved.**

Sometimes for the former we use the word **level**, by which we mean that every point of the surface of the liquid lies in the **same horizontal plane.**

This is true only when the amount of surface is small, for then the **curved** surface almost coincides with a **flat** surface.

We might show that in the following way: Draw two or three circles of different diameters, Fig. 55, and take two points, A

FIG. 55.



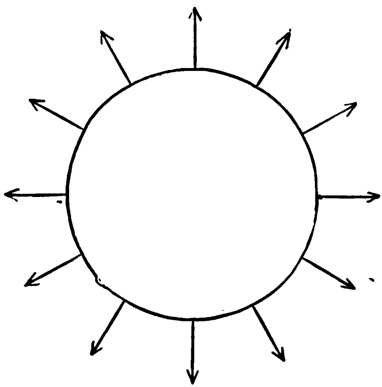
and B, in the circumference of each, the same *curved* distance apart. Then the part of the circle between these two points whose diameter is greatest will more nearly approach *a straight line.*

What is true of a *circle* is also true for a *globe*; the *surface* of the globe of greatest diameter is very nearly a *flat surface*. It is for this reason that we may consider the *surface* of a pond to be **level** or **horizontal**, since the *area* covered by it is such a small fractional part of the surface of the whole earth.

30. **Pressure of liquids.**—In dealing with the properties of a liquid, we must not overlook the various pressures which it is able to exert upon bodies in contact with it.

Pascal discovered that if a liquid be shut up in a vessel and subjected to pressure from without, then *that* pressure would be communicated to every part of the vessel containing the liquid.

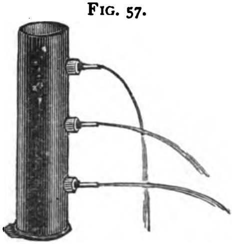
Fig. 56.



This principle can easily be tested by filling a child's indiarubber ball with water, which has previously been pricked with a very fine sewing needle.

When the ball is pressed between the finger and thumb, jets of water are seen to rush out of *every* hole, showing that the pressure *first given* to the ball has been passed on to every part of the ball.

Fig. 57.



In Fig. 56 the arrows denote the jets of water rushing out of the finely pricked holes of the indiarubbber ball.

Secondly, liquids exert pressure upon the sides of a vessel, which is known as **lateral** or **side** pressure, the word **lateral** being derived from the Latin (*latus*, *lateris*, a side).

This may be tested experimentally by the use of the *spouting-jar*. A hollow cylindrical vessel, Fig. 57, closed at the bottom, has three holes made in its side, into which are fitted corks containing

small glass tubes. Now, when the vessel has been filled with water, three jets issue forth, each with a greater force than the one above it.

How do we explain this?

The jet flowing out of the bottom pipe has a great weight of water above it, which is communicated to the hole *horizontally* near the bottom; whereas the middle jet, not having such a large quantity of water above it, is not driven out with such a great force.

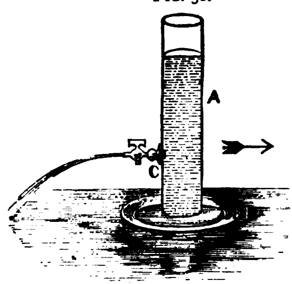
The lesson we learn from this experiment is—**that the pressure upon the side of a vessel increases with the depth** of any point from the surface of the liquid.

Another very good illustration of **lateral pressure** is the motion produced by the flowing of a liquid from the hole in the *side* of a vessel.

In Fig. 58, A represents a thin tin cylinder, floating upon a large flat cork B, with a stop-cock C fitted in the side of the cylinder.

The cylinder having been filled with water, the stop-cock C is suddenly opened, when the cork containing the cylinder is perceived to move away in the opposite direction to that taken by the flowing jet.

FIG. 58.



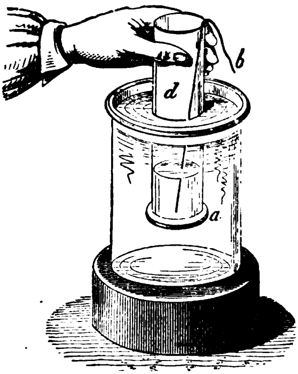
This proves that the horizontal pressures upon the inside of the cylinder balance each other when the tap is shut; but as soon as an opening is made in the side, the water rushes out, thus rendering the pressure upon one side less than upon the other. The cylinder therefore floats upon the water by reason of this unbalanced horizontal force.

In passing, we ought to note that in consequence of the **lateral pressure** of water, dams which enclose a large body of water often give way, their sides not being sufficiently strong to support so great a pressure.

Again, **liquid matter** is able to exert an **upward** pressure When a ship springs a leak, the water rushes with great force through the hole in consequence of the **upward pressure** of the water.

To prove this experimentally, we might take an empty bucket and float it on the surface of a pond, when as fast as it is pushed downwards so fast will it rise again to the surface.

FIG. 59.



This is due to the **upward pressure** which the water exerts upon the bottom of the bucket.

Or, we might prove the same thing by taking a long glass tube, as shown in Fig. 59, open at both ends, and by fitting to one end a very thin disc *a*, of *glass* or *mica*, whose weight for the present we need not consider.

To this *disc* fasten a string *b*, by means of which the *disc* may be kept against the bottom of the glass tube.

If the whole be immersed in water, the *disc* will not fall down, although we no longer hold it by the string. Why is this?

Clearly by the **upward pressure** of the water upon the *disc*, which keeps it in contact with the tube.

31. **Capillary phenomena of liquids.**—When we examine a wineglass which contains a liquid, we observe that the edges of the liquid are slightly rounded off; in the case of water it is curved thus (◡, *concave*), like the inside of a cup, while if *mercury* be employed the curve would be (◠, *convex*), like the outside of a ball.

These phenomena are explained by referring them to the action of a narrow glass tube when it is placed in either of these liquids.

If the tube be plunged into water, or into any other liquid that will *wet* it, the **level** of the liquid *within* the tube, instead of remaining at the same height as it is *without*, **stands higher** (Fig. 61), and this in proportion to the diameter of the tube.

This elevation of the liquid is regulated by the law of *inverse* diameters; for example, if two tubes whose internal diameters are $\frac{1}{8}$ and $\frac{1}{4}$ of an inch respectively be taken, then the rise in the tube whose diameter is $\frac{1}{8}$ of an inch would be **double** to what it is in the tube of $\frac{1}{4}$-inch bore.

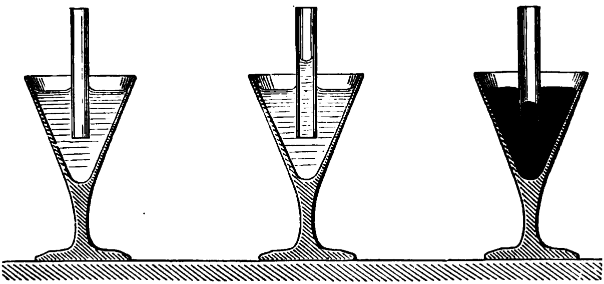
If, however, the tube be dipped into *mercury*, which does

not wet it, then the mercury within the tube will be **depressed,** and will have a **convex** surface.

Now, since these phenomena are more particularly noticeable in narrow tubes than in others, they are termed **capillary phenomena** (from *capillus*, a hair).

In Fig. 60 is shown a solid glass rod dipped in water. Observe how the water rises by the side of the glass rod and also by the side of the vessel, producing a concave surface.

FIG. 60. FIG. 61. FIG. 62.



In Figs. 61, 62, we have glasses containing *water* and *mercury* placed side by side. A hollow glass tube is dipped into each. In Fig. 61 we notice the **ascent** of the water and the **concave** surface within; whereas in Fig. 62 the *mercury* is not only **lower** inside than it is outside, but its surface is **convex.**

32. **Effects due to capillarity.**—First, in explaining the reason why the sap rises in plants, or the oil through the wick of a lamp, we introduce **capillary attraction.**

The small holes which exist between the fibres of the cotton of which the wick is composed act as so many small **capillary tubes** through which the ascent takes place.

Again, in porous substances, such as salt, sugar, wood, blotting-paper, &c., we observe a rising of the liquid when a part of either substance is dipped into it.

The reason for this is apparent.

The **pores,** being so very close together, may be likened to a number of **capillary tubes,** one on the top of the other.

A boy blots his copy-book.

The first thing which occurs to him is to take the corner of

a piece of blotting-paper to suck up the ink. Here the ink rises in the blotting-paper by **capillary attraction.**

Cooks also take advantage of this property by using thin paper to absorb grease from the surface of soups.

A very interesting experiment, which can be tried by every boy, is to take a couple of wineglasses, as seen in Fig. 63, and to connect them with a piece of cotton wick. Very quickly the liquid in the top glass will be transferred to the lower one, the liquid having risen up the wick by **capillary attraction.**

FIG. 63.

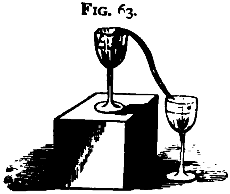


FIG. 64.

Likewise it is owing to this property that oil rises in the wick considerably above the reservoir of a paraffin lamp.

In watering pot-plants it is customary to keep the saucer well supplied with water, so that the plant may feed itself as occasion requires by **capillary attraction.**

Particularly do we notice this when hyacinths are grown in glasses. How beautifully do those long fibres, Fig. 64, immerse themselves in the water below!

QUESTIONS UPON THE SIXTH CHAPTER.

Ques. 1. What do you mean by *capillary attraction?* Name two instances in which we make use of it.

Ques. 2. If you stand a fine glass tube in mercury what do you see? Why?

Ques. 3. Give a few common examples of *capillary attraction.*

Ques. 4. How would you show the upward and lateral pressure of liquids?

Ques. 5. What is the effect of wetting a *porous* body? Give examples, and compare the action with that of a capillary tube.

Ques. 6. Show that there is an *upward* pressure in liquid matter.

Ques. 7. If one end of a skein of silk be placed in a vessel containing a liquid, and the other end be allowed to hang over the side, in a short time the vessel is found to be empty. How can you explain this?

Ques. 8. A small cubical box full of water is placed on a large piece of cork, which is floated on water. Explain what takes place as soon as a hole is made in one side of the box.

Ques. 9. In watering pot-plants it is customary to stand the pot in a saucer of water. Explain how the plant is fed with water.

Ques. 10. Show in what way the burning of an oil lamp is an illustration of *capillary attraction.*

Ques. 11. Distinguish between *viscous* and *mobile liquids.*

Ques. 12. Why do the sides of a large reservoir or dam increase in thickness towards the bottom?

Ques. 13. What are the *two* surfaces that *still* water presents to us? When may we consider a *surface* to be plane?

Ques. 14. If you had *two* liquids given to you, how would you distinguish which of the two is *viscous?*

Ques. 15. What is the difference between *lateral* pressure and *upward* pressure? Give experiments in support of each.

Ques. 16. Describe the *spouting-jar.* What lesson does it teach us?

Ques. 17. Three narrow glass tubes, open at both ends, are given to you. Their internal diameters are $\frac{1}{8}$, $\frac{1}{16}$, and $\frac{3}{16}$ of an inch respectively. When dipped in a tumbler of water, what relation will there be between the heights to which the water will ascend within these tubes?

Ques. 18. Which of the following liquids are *viscous*, and which *mobile*—castor-oil, paraffin-oil, glycerine, treacle, tar, water?

CHAPTER VII.

LIQUIDS—(*continued*).

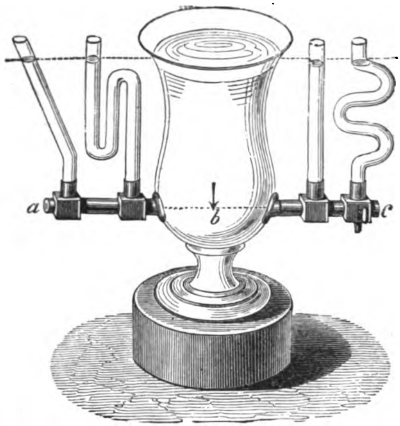
33. Water finds its own level.—34. The water-level.—35. The spirit-level—36. Artesian wells—37. Barker's mill—38. Bramah's press—39. The diving-bell—40. The hydrostatic bellows.

33. **Water finds its own level.**—One of the chief differences between *a solid* and *a liquid* is this—that in the *solid* the force of cohesion is sufficiently great to keep it in one particular shape, whereas in the *liquid* the molecules roll about one over the other so easily that the liquid has the power to shape itself to the vessel which holds it

A very important consequence results from this.

When a liquid is poured into a vessel its molecules spread themselves abroad, causing the top surface to become **plane.**

FIG. 65.



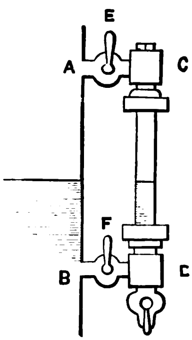
Not merely is this so, but if a number of vessels be joined together, and a liquid be then poured into one of them, it is observed to spread itself abroad in *all* of the vessels, and when at rest the surface of the liquid in each vessel is found to be in one **continuous horizontal plane.**

This principle may be demonstrated by means of the apparatus shown in Fig. 65.

A number of different shaped glass vessels are screwed into the common piece *a b c*.

When water or any other liquid is poured into the central branch, it runs towards *c* and towards *a*, rises in the four branches, until the *five* surfaces settle down in **one continuous horizontal plane.**

FIG. 66.



This fact is often expressed by the words, '**water finds its own level.**'

There are many applications of this principle, but for the present we content ourselves by giving a few only. First, to ascertain the exact height of the water within a boiler, the engineer fits a glass tube in front of it, which enables him at a glance to see how high the water has risen.

In the sketch, Fig. 66, A B represents the front of the boiler, C D a vertical glass tube about 16 inches long.

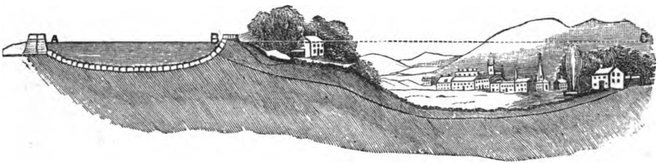
The ends of this tube fit into metal tubes A C and B D, of which the lower one enters the water and the other the steam chest. E and F are stop-cocks by

means of which the communication may be shut off, should occasion arise to fit a new tube C D.

When the cocks E and F are open, from the principle before stated, the water within the tube C D stands at the same height as it is within the boiler.

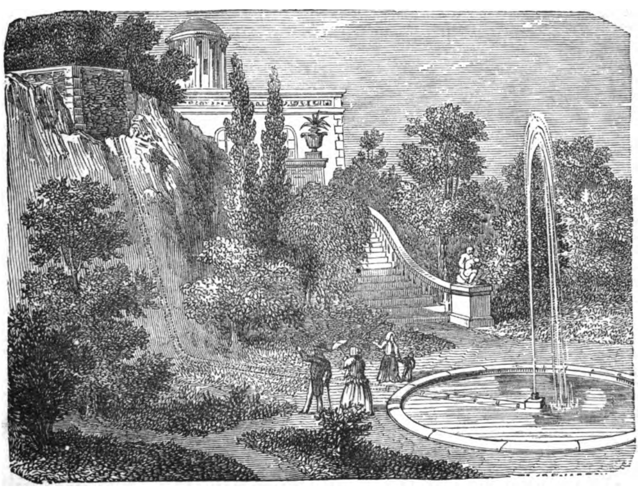
Again, how is water supplied to houses in large towns?

FIG. 67.



A reservoir is first erected at the highest spot in the neighbourhood; pipes are then laid underground, connecting the cisterns of dwelling-houses with the reservoir itself.

FIG. 68.



Then, from the principle that—**water finds its own level,** water will flow from the reservoir along the pipes undergro'

up the connecting pipes, into the various cisterns, provided that in no case is any cistern higher than the reservoir.

Further, the action of *fountains* depends upon this principle.

For the water that spurts out always comes from a reservoir placed in a much more elevated position than where the jet is, the force with which it issues from the jet depending upon the difference of level between the reservoir and the jet.

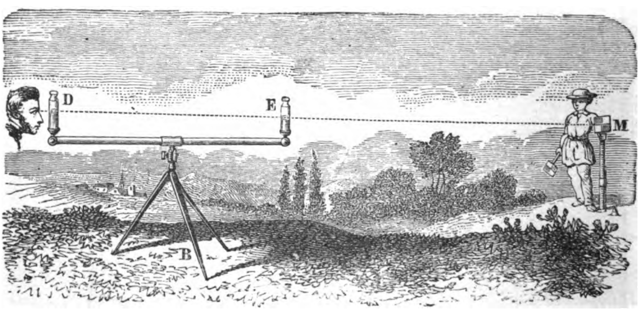
In the diagram, Fig. 68, the reservoir is shown to the left of the figure, the dotted lines indicating the position of the pipes leading from the reservoir to the centre of the pond.

34. **The water-level.**—In Art. 33 it was shown that when water is poured into one arm of a vessel, it has the power to spread itself out and to rise to the same height in all the various branches.

Now, in describing the **water-level** we take knowledge of that fact.

In itself it consists of a metal tube, Fig. 69, bent at right angles at both ends, so as to hold two glass tubes, D and E.

FIG. 69.



When fastened to the tripod B, water is poured into one of the glass tubes. Very quickly it runs along the brass tube, and rises in the other glass tube, settling down, so that the level of the water in both is the same—that is, the surfaces are both *in the same horizontal line.*

Its principal use is to ascertain the difference between the heights of two places. Suppose we want to know how much higher the ground at A is than at B. For the purpose we erect

a levelling-staff at A, which consists of two sliding pieces of wood, supporting a piece of tin-plate M, in the centre of which is a mark.

Now, when this mark is in the line of sight—that is, in the line D E, the height A M is measured.

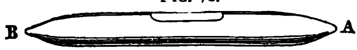
If from the height which D E is above B the distance A M be taken, then the height of A above B can be ascertained.

35. **The spirit-level.**—A moment's reflection will be sufficient to satisfy the reader that it is not always convenient to use the **water-level.**

For instance, suppose we want to test if a bookshelf or a table is horizontal. In these cases the **spirit-level** is found to be of great service.

In its simplest form it consists of a glass tube A B (Fig. 70) filled with spirits of wine, with the exception of a bubble of air left in it, which always tries to occupy the highest part of the liquid. When in use the tube is placed in a case either of wood or of some metal, provided with an opening in the top,

FIG. 70.



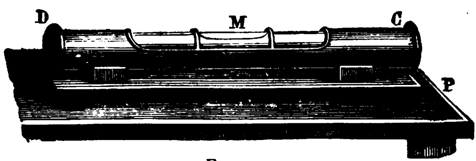


FIG. 71.

as seen in Fig. 71, so as to allow observations to be made of the movement of the air-bubble: for instance, suppose the air-bubble to stop midway between D and C—viz. at M—then we conclude that the surface upon which the **spirit-level** is resting is *horizontal.*

But if the surface is the least bit inclined, then the bubble is seen to rise towards the upper end of the tube.

36. **Artesian wells.**—After rain has fallen it disappears in three ways: some runs off the ground into small streams, brooks, and rivers; some evaporates and mixes with the air in the form of vapour; and the rest sinks into the soil. It is this last method by which rain is got rid of that is of the greatest importance to

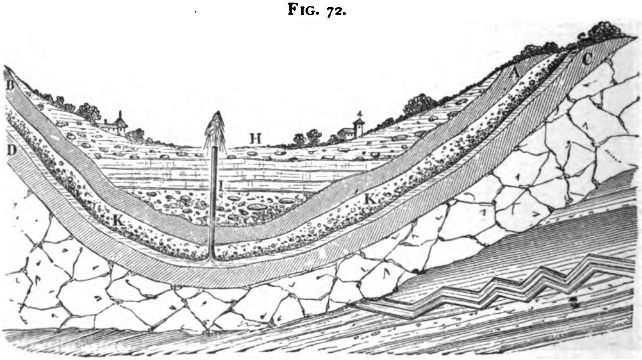
man, for it has to do with the collection of water in the crust of the earth, which is tapped when wells are sunk. Ordinary wells are dug out by hand to the depth of from thirty to seventy feet; but this plan would not do for a very large city or town.

London is built upon a thick clay covered with gravel, and the rain sinks through the gravel into the clay, which is denser and much less easily passed by water.

The clay is a huge mass situated in a basin-shaped cavity, miles in extent, in the chalk; and between the clay and the chalk there are some sands.

Now, the water has gone on collecting through the clay and sands on top of the hard chalk, and by sinking wells into the chalk London has been supplied with pure water at the rate of 20,000,000 gallons a day. An idea of this kind of well may be gathered by turning to Fig. 72, where the layers A B and C D, which are of clay, inclose between them a layer K K of sand.

FIG. 72.



Now, the rain-water which falls on the top part of this layer will naturally filter through it, and will collect in the hollow of the basin.

If a vertical shaft I be sunk down to the layer C D, the water will rise to a considerable height in the shaft while endeavouring to find its own level.

These wells are called **Artesian**, because they were first attempted to be made at Artois, in France.

At Grenelle, near Paris, a well was sunk to the enormous

depth of 1,600 feet, and yet no water came; but at 1,800 feet a hard layer was reached, for they pierced quite through the chalk and got to a hard green sand. Then the water rushed up to the surface H and overflowed at the rate of half a million gallons a day. Moreover it was warm.

The Bath waters rise to the surface and are very hot—too hot to bathe in comfortably.

At Chiswick, when a well of this kind was sunk to a depth of 620 feet, the water rose 4 feet above the level of the ground.

At Tooting so much water rose that a sufficient stream was obtained to turn a wheel.

Likewise in North Africa Artesian wells are met with which have been sunk by order of the French Government. A well in the Sahara desert 156 feet deep produced some small fish three or four inches long; yet the nearest stream was many leagues off, showing that water circulates underground from place to place.

37. **Barker's mill.**—This is a machine constructed to work upon the principle that water presses against the sides of a vessel in proportion to the depth of the liquid.

Mr. Barker selected a tin cylinder, Fig. 73, open at the top, into the sides of which he fitted four pieces of tubing.

FIG. 73.

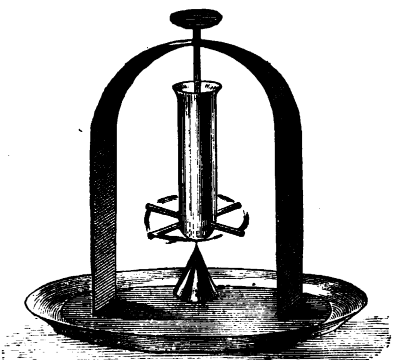
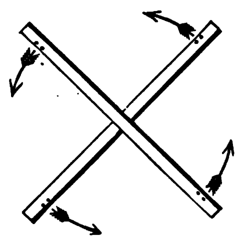


FIG. 74.



In these four tubes small pin holes were drilled horizontally, each pointing the same way. This is shown in Fig. 74.

Through the whole length of the cylinder a stout wire runs, forming an axis for the cylinder to turn upon.

Now, when the cylinder is filled with water, jets are observed to flow from these tiny holes, producing a rotatory motion of the cylinder.

This is accounted for in the same way as in Art. 30, by supposing four unbalanced horizontal pressures to exist, acting directly opposite to these holes, giving it the circular motion.

Some years ago an application of this principle was tried at Devonport.

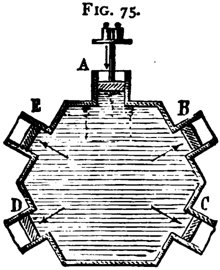
A gunboat named the 'Waterwitch' was fitted with a pump which raised water up a central pipe through a hole in the ship's bottom, and then forced the same out again through holes in the ship's side.

A speed of nine knots an hour was thus obtained from a vessel without either screw or paddle.

38. **Bramah's press.**—All liquids possess the double property of being incompressible and of exerting a pressure in every direction against the sides of a containing vessel. The result of these two properties combined is that, if a vessel be entirely filled with water and completely closed, any outside pressure exerted against the vessel sufficient to force *inwards* any portion of its side *must force outwards* some other portion, the amount of water displaced being exactly equal in both operations.

To understand it fully, suppose we take a vessel of any given form (Fig. 75) and fit into its sides a number of small cylinders of the same internal diameter, at the same time supplying each cylinder with a piston.

FIG. 75.

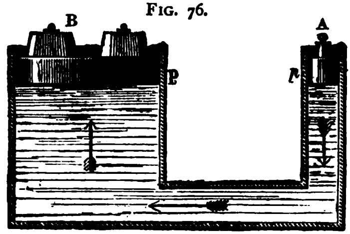


Upon the top piston A let a weight of 1 lb. be placed; this weight of 1 lb. will be communicated to every part of the vessel of the same area as the piston; for it has been found necessary to apply a pressure of 1 lb. inwards to each of the other pistons, B, C, D, E, to prevent them from moving outwards.

Suppose, however, the four pistons are united to form one large piston (as in Fig. 76) whose area is four times that of A, then a weight of 4 lbs. will have to be placed upon B to support the weight of 1 lb. upon A.

This is what is shown in Fig. 76, the arrows denoting the transmission of the pressure caused by the weight upon the piston A.

Fig. 76.



From this we conclude that as many times as the area of the large piston B *contains* the area of the small one A, *so many times* will the weight upon A be communicated to the piston B.

Here, then, we have the principle of **Bramah's press,** known also as the **Hydraulic press,** and **Hydrostatic press.**

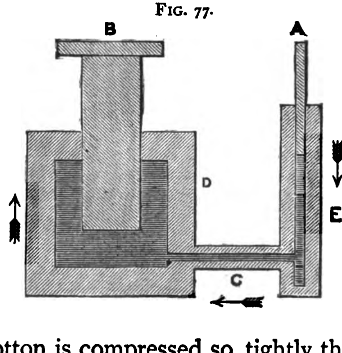
Owing to its great utility, we purpose giving a brief outline of one of these **presses.**

Imagine two stout cylinders D and E to be connected by the tube C, and to be provided with solid pistons B and A, whose areas are in the proportion of 10 to 1. The whole of the interior being filled with water, pressure is applied downwards to the piston A. What happens?

The water in the small cylinder E is forced through the pipe C into the cylinder D, and will push up the piston B.

Now, as the area of B is ten times as great as A, the consequence is—that whatever force is applied to A will be multiplied ten times in its effect upon B.

Fig. 77.



By keeping this fact before them the makers of these presses endeavour to make the piston A as small as possible (consistent with safety) and the piston B as large as possible, so that the force applied to A may be multiplied as many times as possible.

By means of this press cotton is compressed so tightly that bands of iron are necessary to bind it up to prevent it expanding afterwards; and thus very much more cotton can be packed in a ship's hold than could otherwise be done.

By this press the largest ships are not only (as was the case with the 'Great Eastern') pushed from the cradles upon which they were built into the water, but actually lifted bodily out of the water, with their masts and stores on board, to have their bottoms examined and repaired.

Again, when a train leaves the metals, the first thing inquired for is **the jack**, which is in reality a small **press**, by means of which the carriages and engine may be lifted back again on to the rails.

Space will not permit to state all the uses of the **press**, but one other must be mentioned, viz. its application to the **hydraulic lift**, whereby in warehouses and many public offices persons and goods are transferred from the ground-floor to the top story.

39. **The Diving Bell.**—If we take an ordinary wineglass and turn it upside down while we immerse it in a beaker of water, we shall observe that the water rises but a very short distance within the glass. Why is this?

The air within the glass, having been compressed or reduced in volume, has a greater pressure, and presses *downward* in opposition to **the upward pressure** of the water.

Boys can try this experiment for themselves by placing a number of flies in a wineglass before it is put in the water, when they will buzz about, showing that there is air inside the glass. Upon this observed fact the **diving bell** was first constructed.

FIG. 78.

As early as the year A.D. 1538, we read that two Greeks used it in the presence of the Emperor Charles V. and a numerous company of spectators. As a rule it is a large bell-shaped vessel made of iron, open at the bottom and containing seats for several persons.

When lowered by a chain into the water the air within is compressed, which acts *in opposition* to the upward pressure of the water, thus enabling persons seated within to descend in safety to a considerable depth.

To take one illustration: suppose the bell to descend so that the surface of the water within is at a depth of 34 feet below

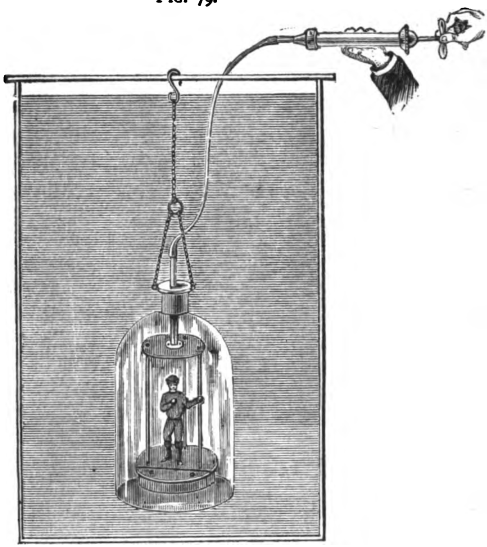
the surface of the river, then the bell will *only* be half full of water.

Then the question arises, how is fresh air supplied to those within the bell?

This difficulty is overcome by the use of a force-pump.

In Fig. 79 is shown a **diving bell**, the method of lowering

FIG. 79.



it down, and the force-pump employed for supplying fresh air to the inmates.

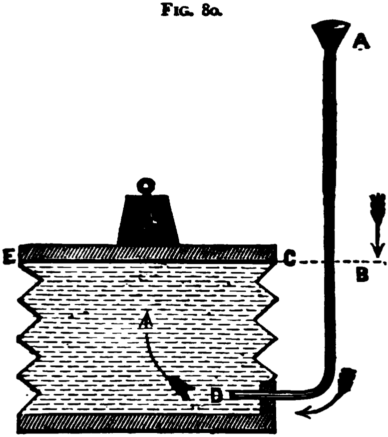
40. **Hydrostatic Bellows.**—Perhaps of all the illustrations given of liquid pressure none will be remembered better than that exhibited by the **hydrostatic bellows**. Two circular stout boards are connected by leather, and when complete the whole resembles a pair of bellows.

Into the bottom board an iron pipe with a bend in it is screwed.

Now, when water is poured into the funnel A (Fig. 80), sufficient to fill the iron pipe A D and the bellows, a heavy weight or a man standing upon the board will be raised as high as the leather will permit.

The reason is this : the weight of water in the tube between A and B is communicated to every part of the bellows.

Fig. 80.



Now, in Bramah's press it was shown that if the *area* of the board E C were 100 times the *area* of the pipe A D, then a weight of 1 lb. at B would support a weight of 100 lbs. on E C ; the only difference between the bellows and the press being that no piston is supplied to the pipe A D.

In the sketch, suppose the area of the pipe to be half of a square inch and that of the board 100 square inches.

Then, since 100 square inches contain half of a square inch 200 times, the weight of 1 lb. of water in the pipe between A and B will be sufficient to support a weight of 200 lbs., if placed on the board E C.

This wonderful result is often called the **hydrostatic paradox.**

QUESTIONS UPON THE SEVENTH CHAPTER.

Ques. 1. How is water supplied to houses in large towns? Illustrate by a diagram.

Ques. 2. Describe a *water-level.* What is its use?

Ques. 3. What is the principle upon which fountains act? Illustrate by a diagram.

Ques. 4. What principle in the movement of liquid matter is at work in the playing of a fountain? Name other applications of the principle.

Ques. 5. Describe a spirit-level, and explain its use.

Ques. 6. Describe the diving-bell.

Ques. 7. Why should a reservoir which supplies a town with water be placed upon high ground?

Ques. 8. Sketch and describe an Artesian well. What important principle is involved in its working?

Ques. 9. Briefly describe the principle and action of Bramah's press.
Ques. 10. Sketch and describe Barker's mill.
Ques. 11. Explain the difference between a *water-level* and a *spirit-level.*
Ques. 12. State in brief language the principle upon which Bramah constructed his press.
Ques. 13. In Barker's mill, what would happen if all the tiny holes became choked with dirt? Why?
Ques. 14. Sketch and describe any arrangement for seeing the height of the water within a boiler.
Ques. 15. Explain how the *water-level* is used in levelling.
Ques. 16. Mention any application of Barker's mill with which you are familiar.
Ques. 17. In the *hydraulic press* the areas of the two pistons are 12 square inches and 1 square inch respectively; what weight placed upon the large piston will balance 2 lbs. upon the smaller one?
Ques. 18. State the various applications of the *hydrostatic press.*
Ques. 19. Sketch and describe the *hydrostatic bellows.*

CHAPTER VIII.

DENSITY AND SPECIFIC GRAVITY.

41. Density—42. Specific gravity—43. Principle of Archimedes—44. Experimental proof of that principle—45. Methods adopted for determining the specific gravity of *solid*, *liquid*, and *gas.*

41. **Density.**—If we weigh *equal* volumes of different substances, we shall find that they have *different* weights.

For instance, equal volumes of *water*, *lead*, and *gold* when weighed will give weights in the proportion of 1, 11, and 19.

This is expressed by saying that the mass of lead is 11 times as **dense** as that of water; or, the mass of gold is 19 times as **dense** as that of water.

Thus then, the **density** of a body refers to the **degree of closeness** with which the particles of a body are packed.

We might give many familiar illustrations of the term: we speak of a **dense** fog and a **dense** crowd. What do we mean?

In the former case we refer to the **closeness** of the watery particles in the atmosphere which renders the fog **so dense**; while in the latter a **dense** crowd gives us the idea that the persons forming it are very closely packed together.

42. **Specific Gravity.**—This is an expression continually

met with in scientific works; not merely in mechanics, but also in chemistry and physics.

As we understand it, it refers to the **special weight** of a given volume of a substance as compared with the weight of an **equal volume** of some standard substance.

Owing to the purity of *distilled water*, we take it as **the standard** (at a temperature of 39 degrees on the Fahrenheit scale, or 4 degrees on the Centigrade)[1] to refer the weights of all solids and liquids to, having the same capacity as the water.

When, therefore, we say the **specific gravity** of gold is 19, we mean that, bulk for bulk, the gold weighs 19 times as much as water; or, in speaking of the **specific gravity** of mercury as being $13\frac{1}{2}$, we mean that, bulk for bulk, the mercury is $13\frac{1}{2}$ times as heavy as water.

43. **Principle of Archimedes.**—An anecdote is told of Archimedes, which practically illustrates the accuracy of his ideas.

Hiero, king of Syracuse, had a certain quantity of gold made into a crown, and suspecting that the workman had taken some of the gold and used a portion of alloy of the same weight in its place, applied to Archimedes to solve the difficulty.

Archimedes, while reflecting over this problem in his bath one morning, observed the water running over the sides of the bath, when it occurred to him that he was *displacing* a quantity of water *equal to* his own *bulk*, and, therefore, that a quantity of pure gold equal in weight to the crown would displace less water than the crown, the *volume* of any weight of alloy *being greater than* that of an *equal* weight of gold.

It is related that he immediately ran out into the streets, crying '*Eureka! Eureka!*' 'I have found it! I have found it!'

From this circumstance the following principle is now known as **the principle of Archimedes.**

Principle.—**Every solid immersed in a liquid loses a portion of its weight, equal to the weight of the liquid displaced.**

Of course it is assumed that no part of the solid is dissolved by the liquid.

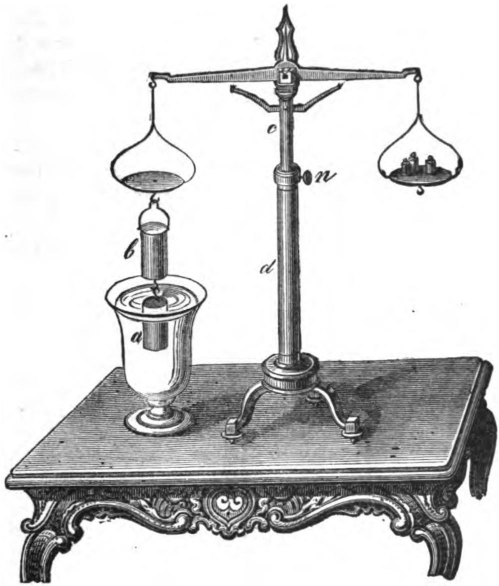
44. **Experimental proof of the principle of Archimedes.**—From one of the scales of a hydrostatic balance (Fig. 81) a *hollow cylinder* of brass *b* is suspended, and below this a *solid cylinder a*, whose volume is exactly the same as the *interior*

[1] The words 'degree,' 'Fahrenheit,' and 'centigrade' will be explained in Chapter X.

volume of the hollow cylinder *b*: these two are balanced by weights placed in the other scale-pan.

Suppose, now, a vessel of water is placed below these

FIG. 81.



cylinders in such a manner that the lower one *a* shall be totally immersed. What happens?

The upward pressure of the water upon it will cause the scale-pan containing the weights to descend.

Again, let us pour water into the hollow cylinder *b*; the beam then gradually returns to its horizontal position, which it will finally accomplish as soon as the cylinder *b* is completely filled with water.

What conclusions may we draw from this?

Is it not that the weight of water in the cylinder *b* is equal to the weight lost by the cylinder *a*, by reason of the upward pressure of the water?

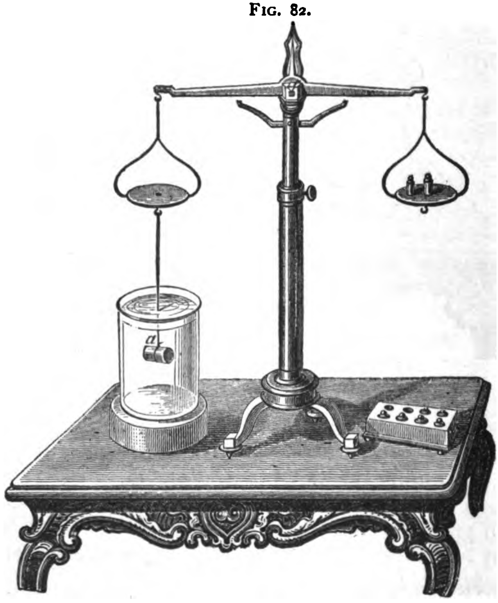
While fully admitting the truth of the **principle of Archi-**

medes, we might be asked the question, Will it increase the pressure upon the bottom of the glass vessel by the immersion of the solid cylinder?

Yes, decidedly. For when we plunge a solid into water, we naturally *raise the level* of the liquid, and since the *pressure* upon the bottom of a vessel depends upon the *height* of the liquid as well as the *area* of its base, the pressure upon the bottom will be increased to the same extent as if we had actually added a volume of water equal to that which the immersed cylinder displaced.

For this reason, a heavily laden barge drawn across a trough-shaped canal, which is built upon pillars over a valley, would produce a greater pressure downwards upon these pillars, since

FIG. 82.



the barge, being heavily laden, would sink to a considerable depth, thus *raising* the *level* of the *water within the canal.*

45. **Methods adopted for determining the specific gravity of solid, liquid, and gas.**

First.—By the use of the *hydrostatic balance.*

Suppose it is a piece of lead whose **specific gravity** we wish to determine.

We first weigh it in the air by suspending it to the hook of one of the scale-pans (Fig. 82).

Let it now be supposed to weigh 820 grains.

Then weigh it again while the lead is immersed in distilled water, as shown at *a* ; the equilibrium will be destroyed on account of the upward pressure of the water.

It now weighs but 749 grains.

This gives us a difference of 71 grains, which is, in reality, the weight of a volume of water equal to the volume of the lead.

Here, then, is a simple problem in arithmetic.

A piece of lead weighs 820 grains, while the *same* quantity of water weighs 71 grains.

How many times is the one heavier than the other?

$$\text{By division, } \frac{820}{71} \text{ gives } 11\tfrac{39}{71}, \text{ or } 11{\cdot}55.$$

This quotient $11\frac{39}{71}$ is the **specific gravity** of the lead.

Ex. 1. A stone suspended from the scale by a fine thread weighs $5\frac{1}{2}$ lbs., but when the scale is lowered so that the stone is in water it weighs only $3\frac{3}{4}$ lbs. Explain this. What is the specific gravity of the stone?

The difference in weight is clearly due to the *upward* pressure of the water, and is the *weight* of a *volume* of water *equal to that* of the stone.

Here then we have the weight of the stone $= 5\frac{1}{2}$ lbs.

$$\left.\begin{array}{r}\text{and the weight of the same}\\ \text{volume of water}\end{array}\right\} = 5\tfrac{1}{2} - 3\tfrac{3}{4} = 1\tfrac{3}{4} \text{ lbs.}$$

$$\left.\begin{array}{r}\text{Therefore the sp. gr. of}\\ \text{stone}\end{array}\right\} = \frac{5\frac{1}{2}}{1\frac{3}{4}} = \frac{11}{2} \times \frac{4}{7} = \frac{22}{7} = 3\frac{1}{7}. \quad \textit{Ans.}$$

Ex. 2. A solid weighing 25 lbs. in air weighs 16 lbs. in one liquid, and 18 lbs. in a second liquid. Compare the specific gravities of these two liquids.

In the first case the weight of the solid $= 25$ lbs.

$$\left.\begin{array}{r}\text{and the weight of an equal volume of}\\ \text{the } \textit{first} \text{ liquid}\end{array}\right\} = 25 - 16 = 9 \text{ lbs.}$$

$$\left.\begin{array}{r}\text{In the second case the weight of an}\\ \text{equal volume of the } \textit{second} \text{ liquid}\end{array}\right\} = 25 - 18 = 7 \text{ lbs.}$$

By comparing the weights of equal volumes of the two liquids we get 9 : 7. *Ans.*

Secondly.—To determine the specific gravity of a **liquid.**

The simplest plan is to employ a **specific gravity bottle**. This consists of a small bottle A of slight blown glass, Fig. 83, with a wide mouth and a hollow stopper B, whose capacity is such that it will just hold 1,000 grains of distilled water at a temperature of 60° F.

FIG. 83.

In determining the **specific gravity** of any **liquid** by means of it, we first ascertain the weight of the empty bottle (the weight of the air within being so small that it is for the present neglected), which in the cut is represented by a brass weight C, and also of the bottle when *filled* with the liquid.

The difference between these two weights gives us the *net* weight of the liquid.

But we also know that the weight of an *equal volume* of water is 1,000 grains.

Hence, if we divide the weight of the liquid by 1,000, we shall obtain the sp. gr. of the liquid compared with water.

Again, we may be asked to explain the expression, the **specific gravity** of mercury is $13\frac{1}{2}$; what does it mean?

If we fill the **specific gravity bottle** with mercury, weigh it when full, and also when it is empty, we shall find that the *net* weight of the mercury is 13,500 grains.

But as the *same volume* of water weighs but 1,000 grains, it follows as a matter of course that the *former* is just $13\frac{1}{2}$ times the weight of the *latter*.

Thus the specific gravity of mercury is $\frac{13,500}{1,000} = 13\frac{1}{2}$.

Ex. 1. A specific gravity bottle when empty weighs 200 grains, and when filled with water and alcohol respectively weighs 1,200 grains and 1,000 grains.

What is the specific gravity of the alcohol?

The *net* weight of the water $= 1,200 - 200 = 1,000$ grains

The *net* weight of the alcohol $= 1,000 - 200 = 800$ grains.

$$\left.\begin{array}{r}\text{Hence the specific gravity of}\\ \text{the alcohol}\end{array}\right\} = \frac{800}{1,000} = \frac{4}{5} \text{ or } \cdot 8.$$

Ex. 2. A specific gravity bottle when empty weighs 200

grains, and when filled with water and milk respectively weighs 1,200 grains and 1,230 grains. What is the sp. gr. of milk?

The *net* weight of the water = 1,200 − 200 = 1,000 grains.
The *net* weight of the milk = 1,230 − 200 = 1,030 grains.
Hence the specific gravity of the milk $= \frac{1,030}{1,000} = 1\frac{3}{100}$ or $= 1{\cdot}03$.

Ex. 3. A specific gravity bottle when filled with distilled water and with sea-water weighs respectively 1,200 grains and 1,228 grains.

What is the sp. gr. of the sea-water, supposing the bottle to weigh 200 grains?

The *net* weight of the distilled water = 1,200 − 200 = 1,000 grains.
The *net* weight of the sea-water = 1,228 − 200 = 1,028 grains.
Hence the specific gravity of the sea-water $= \frac{1,028}{1,000} = 1\frac{7}{250}$ or $= 1{\cdot}028$.

Thirdly.—To ascertain the **specific gravity** of a **gas** or **vapour.**

Gases and **vapours** are generally referred to atmospheric air at the same temperature and under the same pressure as the gases themselves.

For this purpose a large globe of about 2 gallons capacity is used, the neck of which is provided with a stop-cock, so that it can be screwed on to an air-pump.

Having taken all the air out of the globe, the weight of the empty globe can be ascertained.

Then, by filling the globe with the gas in question, and also with the air, we can ascertain the weights of *equal volumes* of air and the gas.

The quotient obtained by dividing the *weight* of the *gas* by that of an equal volume of air gives us its **specific gravity** as compared with air.

To take a numerical example: 100 cubic inches of dry air weigh 31 grains, while the same volume of carbonic acid gas at the same temperature and under the same pressure weighs $47\frac{1}{4}$ grains.

What is the specific gravity of carbonic acid gas?

$$\text{Here } \frac{47\frac{1}{4}}{31} = \frac{189}{124} = 1\frac{65}{124} = 1{\cdot}52. \quad \textit{Ans.}$$

Or, we might have taken 100 cubic inches of hydrogen, which weigh $2\frac{7}{50}$ grains.

$$\text{In this case, sp. gr.} = \frac{2\frac{7}{50}}{31} = \frac{107}{1,550} = \frac{1}{14} \text{ nearly.}$$

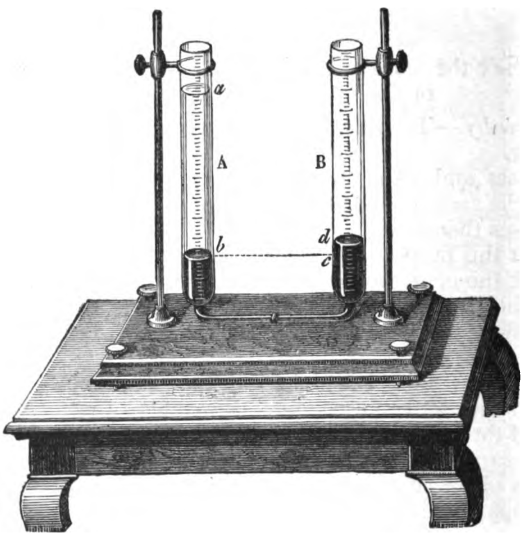
From these figures we learn that hydrogen, which is the lightest of all gases, has for its **specific gravity** $\frac{1}{14}$; that is, air is 14 times as heavy as an equal bulk of hydrogen.

Lastly.—There is yet another practical way of determining the **specific gravity** of a **liquid.**

A tube is bent in the manner shown in Fig. 84, and liquids are poured into its two arms.

Suppose we select *water* and *mercury*, pouring the latter

FIG. 84.



one in first. Very quickly it settles down, so that the two surfaces *b* and *c* are in the same horizontal line.

Now pour distilled water in the arm A, until the mercury has risen 1 inch in the arm B above the common level *b c*.

If the surface of the water *a* be then accurately measured from *b c*, we shall have as a result $13\frac{1}{2}$ inches for the height *a b*.

From which we learn that 1 inch of mercury presses downward in the arm B with the same force as $13\frac{1}{2}$ inches of water do in the arm A; or, in other words, bulk for bulk, mercury is $13\frac{1}{2}$ times heavier than distilled water.

It is for this reason that two liquids which do not mix arrange themselves in the order of their *decreasing* specific gravities from the bottom upwards.

Here we have a pint glass half filled with oil, to which half a pint of water has been added.

How do these liquids arrange themselves?

Since, bulk for bulk, oil is *lighter* than water, we shall have oil at the top while water will find its way to the bottom.

QUESTIONS UPON THE EIGHTH CHAPTER.

Ques. 1. What is meant by the *specific gravity* of a liquid? Mention two liquids of greater specific gravity than water and some of less.

Ques. 2. The *specific gravity* of mercury is $13\frac{1}{2}$. Give an explanation of this. What is the standard of comparison of gases?

Ques. 3. A pint glass is half filled with oil, and to this half a pint of water is added. How do these liquids arrange themselves? Give your reason.

Ques. 4. Carefully explain the method of determining the *specific gravity* of a solid.

Ques. 5. Explain the term 'specific gravity.' What was the discovery about 'specific gravity' that was made by Archimedes?

Ques. 6. A stone suspended from the scale by a fine thread weighs $5\frac{1}{2}$ lbs., but when the scale is lowered so that the stone is in water it weighs only $3\frac{3}{4}$ lbs. Explain this. What is the *specific gravity* of the stone?

Ques. 7. What is the common method of comparing weights of different bodies?

Ques. 8. If a heavily laden barge be drawn through a trough-shaped canal which is built upon pillars over a valley, would there be any danger? Why?

Ques. 9. A certain volume of olive oil weighs 91 grains, and the same volume of water weighs 100 grains; what is the *specific gravity* of the oil?

Ques. 10. Sketch and describe the *specific gravity bottle.* How would you use it?

Ques. 11. State how you would proceed to find the *specific gravity* of a gas—for instance, *oxygen* or *hydrogen.*

Ques. 12. The *specific gravity* of diamond being $3\frac{1}{2}$, and the weight of a certain volume of it is $3\frac{1}{2}$ oz. What would be the weight of an equal volume of water?

Ques. 13. Supposing the weight of a cubic foot of copper to be 8,900 oz., and that of the same volume of distilled water to be 1,000 oz., what is the *specific gravity* of copper?

CHAPTER IX.

BUOYANCY OF LIQUIDS AND GASES.

46. Buoyancy—47. Buoyancy of air—48. Applications of the buoyancy of gases—49. Applications of the buoyancy of liquids—50. The lactometer—51. The hydrometer.

46. **Buoyancy.**—In discussing the pressure which liquids exert upon bodies immersed in them, we had occasion to speak of the **upward pressure** of the liquid.

This **upward pressure** is often termed the **buoyancy** of the liquid, since the liquid is observed to **buoy** or lift the body up.

Several illustrations of this have already been given; for instance, *the Archimedean experiment*, mentioned in the last chapter, in which a body totally immersed in a liquid *lost* a part of its weight, through the **buoyancy** or **upward pressure** of the liquid.

Our object in this chapter is to show how true this is—for *gases* as well as for *liquids.*

47. **Buoyancy of air.**—Why do pieces of paper fall through the air slowly while a stone falls very quickly?

If we consider the relative densities of *air*, *paper*, and *stone*, we shall conclude that it is through the **buoyancy** of the air that they do not reach the ground in the same time.

To prove this, we have only to refer to the experiment performed by Sir Isaac Newton.

This philosopher selected a tube about 6 feet in length, Fig. 85, which was closed at one end and fitted with a stop-cock at the other end.

After placing within the tube pieces of *lead*, *paper*, and *feathers*, it was connected with an air-pump, so that all the air within could be withdrawn.

The tube having been disconnected, it was turned quickly upside down, when it was observed that the *lead*, *paper*, and *feathers* fell with the same rapidity. Suppose, however, the air to be readmitted and the experiment repeated, then the *three* fall with different degrees of rapidity, showing that it was due to the **buoyancy** of the air within the tube that the one reached the bottom before the other two; and this in proportion to the relative densities of the three substances—

that is to say, the *lead*, whose specific gravity is greater than that of the *paper*, would reach the bottom first.

For a class experiment the piece of apparatus known as

Fig. 85.

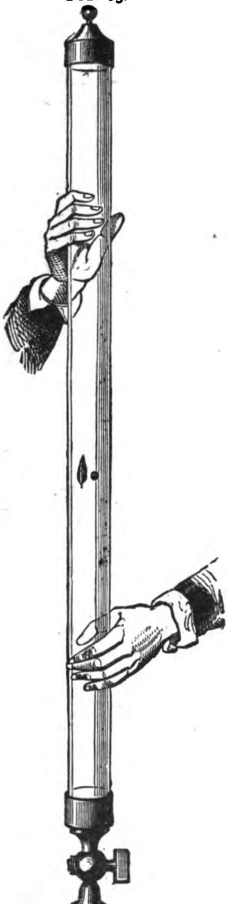


Fig 86.

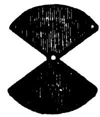
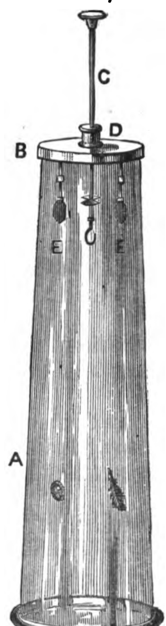


Fig. 87.



the *guinea and feather apparatus*, Fig. 87, is very often employed to bring home the truth of the above statement.

It consists of a tall glass receiver A, open at both ends, the surfaces being ground smooth, so that one end will be air-tight when placed upon the plate of an air-pump; while to the other end a ground brass plate B is fitted.

Through this brass plate passes a sliding rod C, which is kept air-tight by means of the stuffing-box D.

To the under side of the brass plate are fitted two trapdoors E, E, which can be kept horizontal or may be allowed to hang vertically (as shown in Fig. 87), according to the position of the sliding rod.

The experiment is performed in the following manner:—

Having well greased the plate of the air-pump, we stand the receiver A upon it.

The trapdoors E, E, are then placed in a horizontal position, and kept there by a disc attached to the end of the rod C. Upon these two trapdoors the *guinea* and *feather* rest.

The brass plate having been put into its place, the receiver is gradually exhausted of its air by means of the air-pump.

Now if the rod C be turned round, so as to release the trapdoors E, E, at the same time, then the *guinea* and *feather*, having no air to **buoy** them up, will strike the plate of the air-pump at the same instant.

If, however, the experiment is repeated without depriving the receiver of its air, then the **buoyancy** of the air will considerably retard the motion of the *feather*.

In Fig. 86 is shown the shape of the *disc* fitted to the end of the rod C, so that it may be able to hold up or to release the trapdoors E, E.

48. **Applications of the buoyancy of gases.**—One of the most important applications of the **buoyancy** of **gases** is seen in the *balloon*.

Our first account of the balloon dates back to the year 1783, when the brothers Joseph and Stephen Montgolfier, of Annonay, constructed them of paper, or of paper covered with cloth.

The balloon made by them was of the form of a globe, at the lower end of which a hole existed to allow hot air to ascend into it.

This was brought about in the following manner:—

Across the open end *a boat* was suspended, in which combustible matter was placed.

From this boat hot air rose to fill the balloon, which had

the effect of making the balloon much lighter than the *same volume* of outside air.

In Fig. 88 is shown one of those fire-balloons named *Montgolfière*, after the brothers who first used them.

FIG. 88.

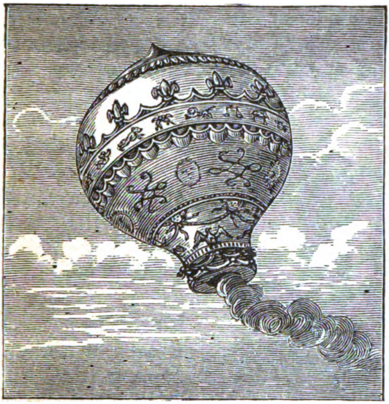
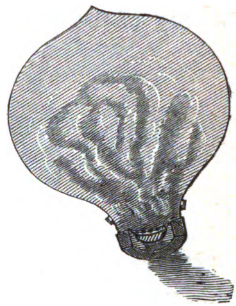


FIG. 89.



Since that time balloons have been filled with *hydrogen gas* and *coal gas*, owing to their lightness and being less dangerous; for in those fire-balloons there was always a certain amount of risk of the material taking fire.

One of the most remarkable ascents was made by Mr. Glaisher and Mr. Coxwell, who ascended in a large balloon containing 90,000 cubic feet of coal gas to the height of 29,000 feet. At this height the cold was so intense that Mr. Glaisher fainted.

As yet we have not stated the reason why a balloon rises.

The gas which fills the balloon being of less density than the surrounding air, it has therefore the tendency to raise the balloon in the air until the inflated balloon reaches a layer of the same density as its own; the force of ascent being equal to the difference between the **buoyancy** of the air and the **weight** of the ascending balloon.

It is very important to bear in mind that a balloon should *not* be quite full of gas; for, as it ascends into the higher regions of the atmosphere, where the pressure of the air is less,

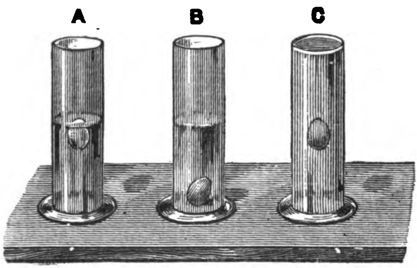
the gas inside, expanding by virtue of its elasticity, would there tend to burst the balloon.

If the weight of the displaced air exceeded that of the balloon by 10 lbs., it would be found quite sufficient for the balloon to rise as far as it is really advisable to go.

49. **Applications of the buoyancy of liquids.**—*Iron* sinks, *cork* swims in water. Why is this?

In the first case, the **density** of the *iron* is greater than the **density** of the water, and since the **buoyancy** of any liquid depends upon its **density**; it follows, therefore, that the water is unable to support the *iron*.

FIG. 90.



In the second case, *cork*, bulk for bulk, is lighter than water. Hence the **buoyancy** of the water is sufficient to support the cork.

A very interesting experiment to prove that the **buoyancy** of a liquid *depends* upon its **density** is performed in the following manner.

Two glass cylinders, A, B, containing pure water, are placed side by side upon a table. In the cylinder B an egg is placed. At once it sinks to the bottom, because the **buoyancy** of the water is not sufficient to keep it up.

If salt be added to the water in the cylinder A, it will increase its density, and thereby increase its power of buoying up; for the egg on being placed in the salt water will no longer sink to the bottom, but will float on its surface.

Further, if the contents of the two cylinders A and B be poured into a third cylinder C, a liquid of different density will be formed, such that the egg will remain at rest in a layer of the liquid whose density is equal to that of its own.

As an application of this principle, we might refer to a ship which has been loaded in a fresh-water river.

While there it sinks to a certain depth marked on the side, called the *load-line*.

Now, when the vessel puts out to sea the *load-line* no longer coincides with the surface of the water, for it is much higher;

thus showing that the greater density of sea-water has rendered it **more buoyant**, thereby raising the ship out of the water.

Again, boys are very much amused when they see their *marbles*, *pieces of slate-pencil*, *pennies*, or even *pieces of iron*, floating upon the surface of *mercury*.

If we compare the *specific gravities* of all these substances with the *specific gravity* of mercury, we shall find that they are all less than it, so that in determining what metals float on *mercury* and what metals sink, all that we require to know is whether their specific gravities are greater or less than that of *mercury*.

Turning to the table below, we notice that *mercury* has for its *specific gravity* 13·6.

Now, by arranging the specific gravities of all the metals in two columns of *greater* or *lesser* specific gravity than that of *mercury*, the answer may be at once obtained.

Greater than that of Mercury.

	Sp. Gr.
Platinum	22
Gold	19
Mercury	13·6

Less than that of Mercury.

	Sp. Gr.
Lead	11·4
Silver	10·5
Copper	8·9
Bronze	8·4
Brass	8·4
Iron	7·8
Tin	7·4
Zinc	7·0

Thus we learn that the only *two* which will **sink** in mercury are *gold* and *platinum*; while all the others—viz., *lead*, *silver*, *copper*, *brass*, *bronze*, *iron*, *zinc*, and *tin*—**float** on its surface.

Further, in order to raise ships sunk in a river, *lighters* are moored over them which are so full of water that they barely float.

When in this position huge chains are placed under the ship in question, which is lying at the bottom of the river (as shown in Fig. 91), and are then connected with the two lighters A and B.

The water having been pumped out of the *lighters*, they naturally try to rise to the surface through the **buoyancy** of the water, at the same time lifting the ship up from the bed of the river.

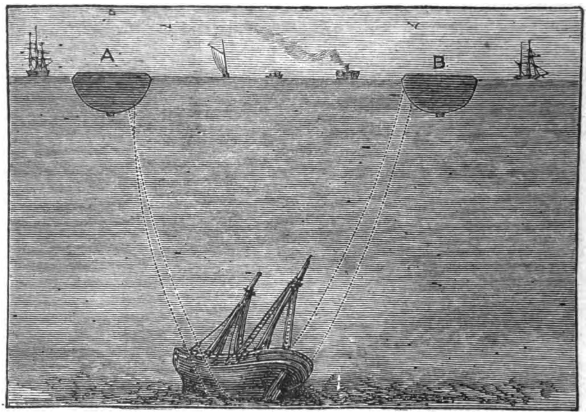
Tugs are then employed to tow these lighters with their submerged burden to a suitable spot, where the ship can be beached.

A very successful experiment of this kind was recently tried in Liverpool, where a ship, the 'Locksley Hall,' laden with grain was raised from a spot near the Mersey Tunnel and safely beached close to the Tranmere Ferry.

On this occasion four old hulks were employed, averaging 500 tons lifting-power each.

Ropes measuring nine inches round, with breaking strains of

FIG. 91.



250 tons and straps of two seven-inch ropes, were placed under the ship's keel, thus forming slings.

At low water the vessel was connected to these four hulks, and as the tide rose the sunken ship, which now rested upon these slings, rose too.

In about three hours tugs took the hulks in tow, bringing the ship with them, eventually beaching it at Tranmere Bight.

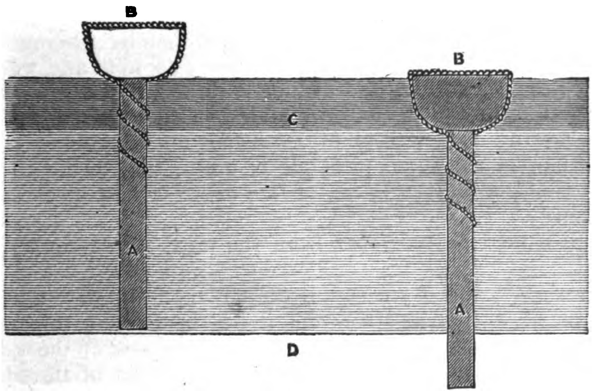
The next day the experiment was repeated, when it was removed a little higher up the river and placed in such a position that the defects might be attended to. It was estimated on this occasion that the ship with its contents weighed over 2,400 tons.

Lastly, in removing wooden piles which have been driven into the bed of a river during the construction of a bridge, it is

customary to saw them off close to the water's edge during low water.

A barge is then floated over each one and filled with water. When the barge has been chained to the pile, Fig. 92, the water is pumped out; the **buoyancy** of the water, together with the rising tide, then tend to raise the barge, and while

FIG. 92



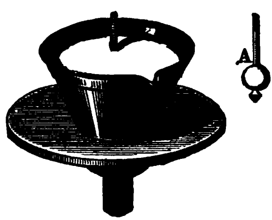
so doing the pile is forcibly drawn out from its place in the bed of the river.

50. **The Lactometer.**—Another very important application of the **buoyancy** of liquids is met with when testing the density of milk.

The instrument we use for the purpose is termed a Lactometer (from the Latin, *lac*, *lactis*, signifying milk).

It consists of a small glass tube A, Fig. 93, loaded at one end with mercury or shot, and with a bulb blown in between the two ends, to render it **buoyant**.

FIG. 93.



It is constructed to work upon the principle—that the greater the density of a liquid, the greater will be its power of **buoying** up a body.

The instrument is first floated in a vessel containing pure *milk*; and the point to which it sinks is marked upon the stem and called zero (o).

Mixtures are then made of *milk* and *water*, viz., nine parts of milk to one part of water, eight parts of milk to two parts of water, seven parts of milk to three parts of water, and so on.

The Lactometer is then floated in each of these mixtures, and marks are made on the stem indicating the depths to which it sinks in each mixture.

The stem thus becomes *graduated*, so that by placing the instrument at any future time in a mixture of milk and water, and by noticing the depth to which it sinks, we may infer the amount of water which has been added to the milk.

In testing the density of *sea-water* an instrument constructed upon the same principle is used; but, owing to its great liability to breakage, *tin*, or *thin brass*, is used in its construction.

It is named **Salinometer,** from the word *saline*, signifying salt.

51. *Lastly*, **the Hydrometer.**—In computing the specific gravities of a *solid* and a *liquid*, it has been found of great service to ascertain the weight of a *certain volume* of the *solid* or *liquid*, and then to compare it with the weight of the *same* volume of water.

This the **Hydrometer** readily does, especially the one constructed by Mr. Nicholson.

The apparatus consists of a hollow metal cylinder, Fig. 94, to which is fixed a cone *d* loaded with *lead*.

To the top of the cylinder a fine metal stem *c* is soldered, which carries at its top end a pan *a*.

On the stem a standard mark *c* is made, to which, at all times, the instrument should be immersed; so that, in whatever liquid the instrument is sunk, the *same volume* of liquid will be displaced.

Now, the condition for any body to float is—**that the weight of the body shall be equal to the weight of the liquid it displaces.**

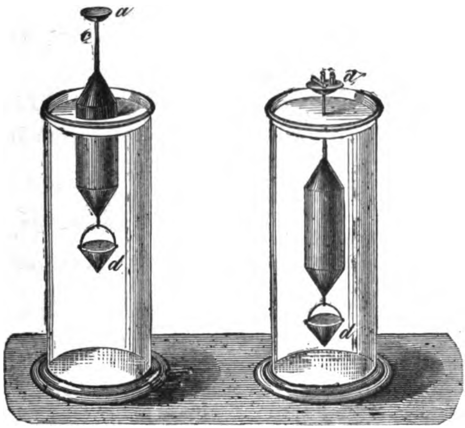
Knowing this, we can obtain the *weights* of the liquids displaced by the Hydrometer when floating in each, and then by comparing them it will give us the specific gravity of one liquid as compared with that of the other.

To take an illustration.

Suppose we want to ascertain the specific gravity of *milk.*.

The apparatus when first placed in water is observed to float with a considerable portion of its volume above the

FIG. 94. FIG. 95.



surface, as shown in Fig. 94; so that the first step will be to ascertain the weight required to be placed in the scale-pan *a* to sink the instrument to the mark *c* (Fig. 95). Suppose this weight to be 100 grains.

Then repeat the experiment to ascertain what weight would be required in the scale-pan *a* to sink the instrument to the same depth in *milk.*

Suppose this weight to be 121 grains. Then, by assuming the instrument itself to weigh 600 grains, we have in the first case 700 grains as the weight of the *water* displaced, and in the second case 721 grains as the weight of the displaced *milk.*

By comparison—that is, by dividing the *second* result by the *first*—we get $\frac{721}{700}=1{\cdot}03$ as the specific gravity of milk.

Ex. A Nicholson's Hydrometer weighs 6 oz., and it is required to place weights of 1 oz. and $1\frac{1}{2}$ oz. in the pan *a* to sink the instrument to the same point in two different liquids. Compare the specific gravities of the two liquids.

$$\left.\begin{array}{r}\text{The weight of liquid displaced}\\ \text{in the first case}\end{array}\right\}=6+1=7\text{ oz.}$$

$$\left.\begin{array}{r}\text{The weight of liquid displaced}\\ \text{in the second case}\end{array}\right\}=6+1\tfrac{1}{2}=7\tfrac{1}{2}\text{ oz.}$$

By comparing 7 oz. with $7\frac{1}{2}$ oz. we have the two specific gravities in the proportion of 14 to 15. *Ans.*

QUESTIONS UPON THE NINTH CHAPTER.

Ques. 1. Why do pieces of paper fall through the air slowly and a stone quickly?

Ques. 2. Why does a balloon rise?

Ques. 3. Iron sinks, cork swims in water. Why?

Ques. 4. How can you show that coal gas is lighter than air? What use is made of this lightness?

Ques. 5. If a balloon is sent up quite full, it will probably burst after rising to a great height. Why is this?

Ques. 6. Why do bodies float? Name some bodies that will float in *air*, *water*, and *mercury*.

Ques. 7. What is a Lactometer? If the same instrument were used in testing *salt water*, what name would you then give to the instrument?

Ques. 8. Describe a method of removing piles in deep water.

Ques. 9. A ship, when loaded in a fresh-water river, sinks to a certain depth, but when it goes out to sea its load-line is above the water's edge. How do you explain this?

Ques. 10. Sketch and describe Nicholson's Hydrometer. How would you compare the specific gravities of *two* liquids by means of it?

Ques. 11. Explain the meaning of the word *buoyancy*. Which has the greater power to *buoy* up the same solid—*mercury* or *water*? Why

Ques. 12. Give Newton's experiment to prove that air *buoys* up bodies falling through it.

Ques. 13. What do you mean by the *guinea and feather* experiment? What lesson does it teach us?

Ques. 14. State what you know about the first balloon constructed. What caused it to ascend?

Ques. 15. What sort of appliances would you make use of to raise a sunken ship?

Ques. 16. A Nicholson's Hydrometer weighs 8 oz., and it is required to place weights of 2 oz. and 4 oz. respectively in the pan at the top to sink the instrument to the same point in two different liquids. Compare the specific gravities of the two liquids.

Ques. 17. A Nicholson's Hydrometer weighs 600 grains; the weights required to sink it to the same depth in *water* and *milk* respectively are 100 grains and 121 grains. Find the specific gravity of milk.

CHAPTER X.

EFFECTS OF HEAT AND COLD UPON LIQUIDS.

52 Liquids expand by heat — 53. The thermometer — 54. Maximum density of water—55. Liquids are converted into gases and vapours under the influence of heat—56. Cold due to evaporation—57. Viscous liquids become mobile under the influence of heat.

52. **Liquids expand by heat.**—What does this mean? In a few words, that **liquids** take up **more room** when they are *hot* than when they are *cold*.

A very simple experiment will bring this home to the mind of the reader.

A saucepan nearly full of water when placed on the fire indicates this by the water running over into the fire long before it reaches its boiling-point.

For a class experiment we usually take a flask, Fig 96, into the neck of which a cork has been fitted, and through which cork passes a piece of fine glass tubing.

FIG. 96.

The flask and part of the tube having been filled with water coloured with a little magenta dye up to the mark A, they are then lowered into a saucepan of boiling water. What do we observe?

First, the level of the water within the tube sinking to the point B.

This can be explained by considering the **expansion** of the flask itself, thereby giving more room for the water.

Very shortly afterwards, however, we notice the *level* of the water rising higher and higher, until the water flows over the top of the tube C.

Here, then, we perceive that heat has so far affected the water within the flask, that the room given to it at first is not sufficient ; and as the water is not able to expand sideways nor downwards without breaking the flask, it therefore **expands** upwards and makes its exit over the top of the tube.

Secondly.—For a moment let us observe the result of **cooling** the liquid.

If the flask be now put in a cold place, the level of the water will gradually sink.

This will be very slow, however, as there are *two* causes at work at the same time which will affect it, viz. the **contraction** or **shrinking** of the glass and the **contraction** of the water within ; the former tending to push the liquid up the tube, the latter to make it sink.

FIG. 97.

FIG. 98.

FIG. 99.

Thus, then, the experiment teaches us that **heat causes a liquid to expand**; and **cold**, which is a word signifying the absence of heat, **causes it to contract**.

53. **The Thermometer.**—Simple as the last experiment may appear, nevertheless it is from the observance of **these two effects** that all thermometers are constructed.

The word **thermometer** is derived from two Greek words : *thermos*, signifying heat, and *metron*, a measure ; and is the name given to any instrument which will measure the **temperature** or **hotness** of a body.

In its simplest form it consists of a glass tube with a very fine bore, terminating in a spherical *bulb* (Fig. 97).

When ready for use, the *bulb* and a part of the stem are

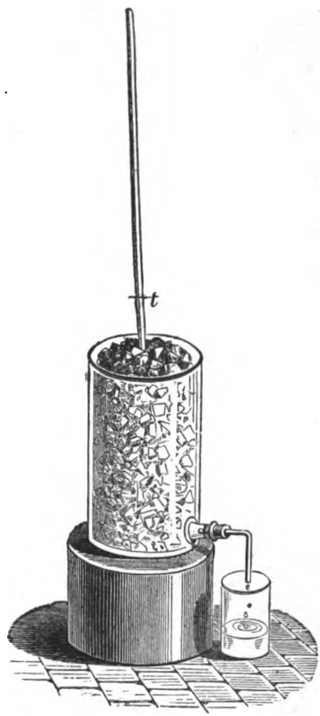
filled with some liquid, Fig. 99, either *alcohol* or *mercury*, the top end being likewise sealed up.

Its actual inventor is not known, but it has been attributed to Galileo, Drebbel, and Robert Fludd.

This we know: that it was Edward Halley who in 1680 first introduced *mercury* as the liquid peculiarly suitable for the thermometer.

Now for a few words about the method of **graduating** a thermometer, as it is very important that every boy, seeing it in his class-room, should know what the divisions and figures upon the thermometer indicate.

FIG. 100.



First.—It is well-known that ice always melts at the same temperature, and that distilled water under the same pressure will boil at the same degree of heat.

This being so, to obtain the **freezing-point** or **zero** of the scale the thermometer is placed in a vessel containing melting snow or powdered ice.

In Fig. 100 such a vessel is shown, with a small drain-pipe at the bottom to allow of any water which has accumulated to escape.

The bulb and a portion of the stem are there surrounded by pounded ice, which after a short time will cause the mercury within the tube to sink to a certain point and there stop.

This point is indicated by the letter *t* in the sketch, and will hereafter be called the **freezing-point** or **zero** of our scale.

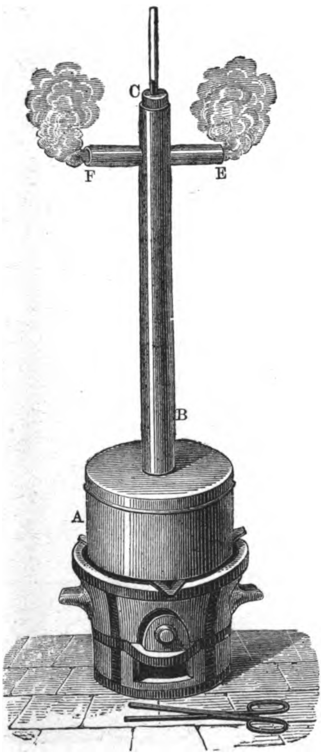
Secondly.—The **boiling-point** of distilled water will be obtained by another piece of apparatus shown in Fig. 101.

It consists of a tin vessel A containing distilled water, through the lid of which passes a long tube B.

The thermometer having been placed inside this tube, it is kept in its place by a cork C.

Now, when the water at A is heated to its boiling-point, the bulb of the thermometer will be surrounded by steam as it passes up the tube B, on its way out through the side holes E and F.

FIG. 101.



The steam being at the same temperature as the water from which it came, the height of the mercury within the thermometer will provide us with the **boiling-point** of the scale.

Thus far we have ascertained *two* points upon the stem, viz. where the mercury **remains** when the bulb is exposed to a freezing temperature, and also when it is exposed to the heat of boiling water.

All that remains to be done is to divide the distance *between* these two points into a number of equal parts, which are called **degrees**.

There are three methods by which this is usually done.

First.—There is the plan adopted by **Fahrenheit**, the one most familiar to us in England.

He started by calling the **freezing-point** 32° (degrees) and the boiling-point 212° (degrees), thus dividing the *distance* between the **freezing-point** and **boiling-point** into 180 parts.

Secondly.—The **Centigrade** or **Celsius** scale, the one met with in France and on the Continent.

In this scale he prefers to call the **freezing-point** 0 and the **boiling-point** 100.

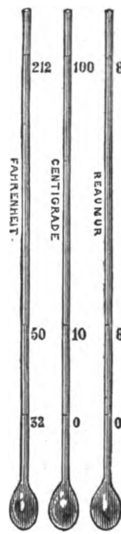
Thus the same distance is divided off into 100 equal parts, instead of 180 as in the **Fahrenheit** scale.

Here, then, we have a connecting link between the two scales, **Centigrade** and **Fahrenheit**; viz., 100 degrees **Centigrade** are equal to 180 degrees **Fahrenheit**, or 5 degrees **Centigrade** are equal to 9 degrees **Fahrenheit**.

Thirdly.—There is the **Réaumur** scale, which is used in Russia more particularly.

The only difference between this and the last one mentioned is the substitution of 80 degrees for the **boiling-point**; that is to say, 80 degrees **Réaumur** are equal to 100 degrees **Centigrade**, or to 180 degrees **Fahrenheit**.

FIG. 102.



To see the relations of the three scales to each other at a glance we write them thus:

$$180° \text{ F.} = 100° \text{ C.} = 80° \text{ R.}$$
or $$9° \text{ F.} = 5° \text{ C.} = 4° \text{ R.}$$

In Fig. 102 the three scales are placed side by side, showing that it is the *same* distance which is divided off into 180, 100, and 80 equal parts respectively.

One other point before we pass from the study of the thermometer, which is this: Why do we use *alcohol* in preference to *mercury* when filling a thermometer?

When mercur, is exposed to a temperature of about 40° C. below freezing-point it becomes solid, resembling a mass of lead; and since with the greatest cold *alcohol* has never been reduced to a solid, we use it for registering very low temperatures.

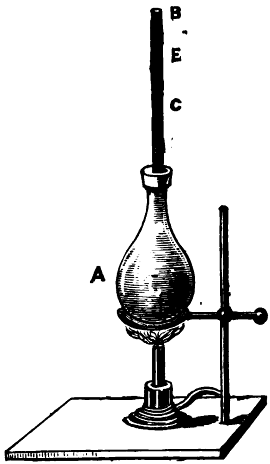
54. **Maximum Density of Water.**—In the early part of the chapter experiments were referred to which show that liquids **expand** under the influence of heat and **contract** by reason of cold.

Water, however, presents a remarkable exception to that rule as its temperature is lowered from 50° F. to 32° F., or, which is the same thing, from 10° C. to 0° C.

A flask A. Fig. 103, containing water which has been slightly

coloured with some magenta dye, is heated until the water runs over the top of the pipe B.

FIG. 103.



It is then placed in a mixture of pounded ice and allowed to cool.

Down to 39·2° F. or 4° C. we observe the level of the water in the tube *to sink*, indicating a **contraction** of the water within the flask. Suppose the letter C to indicate the level of the water at this temperature; as the water is further cooled below this point (viz. 39·2° F. or 4° C.), *an ascent* of the water within the tube is observed to take place, viz. to E.

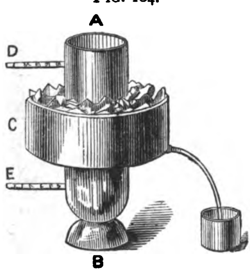
What does all this show?

Clearly that water in the act of cooling **contracts** to a certain temperature (39·2° F. or 4° C.), and then it **expands**.

Nor is this all, for Mr. Hope, by a very ingenious contrivance, proved that water at this temperature has its greatest density—that is, bulk for bulk, has the greatest weight.

For the purpose he took a glass vessel A B, Fig. 104, having two holes in the side to allow of two thermometers D and E being inserted.

FIG. 104.



The vessel having been filled with water, it is then surrounded by a jacket C, containing pounded ice.

Now, as the water in the centre of the vessel gets cold its density increases, and therefore it will naturally sink to the bottom.

This goes on until the water in the lower part of the vessel reaches a temperature of 4° C. or 39·2° F., as shown by the thermometer E; while, strange to relate, the thermometer D, near the top of the vessel, registers a temperature of 0° C. or 32° F.

Now, if the experiment be reversed, viz. by taking the vessel A B into a warm room, where the temperature is 10° C. or 50° F., the water within meanwhile being at the freezing-point, we shall observe the water to sink to the bottom as it is heated; the lower thermometer E rises to 4° C. or 39·2° F., while the thermometer D shows but a temperature of 0° C. or 32° F.

What does this show?

Simply that water at 4° C. is heavier than water at its freezing-point.

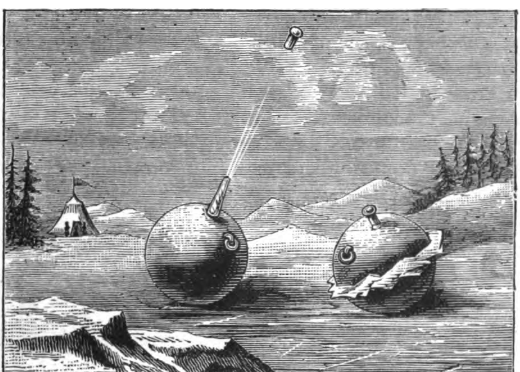
This phenomenon is of very great importance, as we shall hereafter show.

First.—Why does ice float on the surface of water from which it formed?

Our answer to the question is—that the surface water, although colder than the water below it, is lighter, which enables it to remain upon the surface and ultimately to freeze.

Fish are thus protected by the ice, since the water beneath seldom falls below 4° C., a temperature at which life is not destroyed.

FIG. 105.



Secondly.—Why do water-pipes burst in frosty weather?

We can best answer this question by relating the experience of Major Williams in Canada.

Having filled a 13-inch iron bomb-shell with water, he firmly

closed the hole with an iron plug and exposed it to the frost. After some time the iron plug was forced out, accompanied by a loud report, the plug being thrown to a distance of more than 100 yards, followed by a cylinder of ice 8 or 9 inches long through the opening.

In a second experiment of the same kind the stopper resisted the expansive force, but the shell itself was cracked, and a ring of ice, as shown to the right of Fig. 105, was forced through the crack all around the shell.

Here, then, we see that water in cooling from its *maximum density* (4° C.) to 0° C. **does not contract,** but **expands.**

Likewise, at the moment water becomes solid it undergoes **further expansion.**

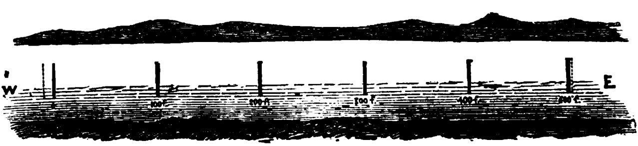
Now imagine water to be shut up in a pipe : is it any wonder that the pipe bursts when the temperature falls so low that the water is converted into a solid of greater dimensions than it had upon entering the pipe ?

An interesting experiment bearing upon this is related by the Rev. Frederick Gardiner, and communicated to the 'American Journal of Science.'

The Kennebec River, near the town of Gardiner, is about 700 feet wide ; the water is very fresh for many miles below, and the average ebb and flow of the tide is five feet ; the depth of the water varies, according to the locality and state of the tide, from 17 feet to 25 feet.

In the course of the winter the ice is always observed to crowd ashore, crumpling up in ridges on the flats and near the edge of the channel. This process was well advanced when Mr. Gardiner commenced his experiment on February 6.

FIG. 106.

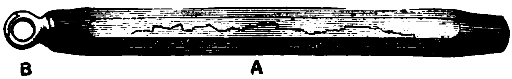


A row of stakes was planted in the ice, as shown in Fig. 106, by boring holes through to the water, at distances of about 100 feet apart, avoiding a very near approach to the shore. The distance between the eastern and western stakes was 500 feet. On March 18 it was found that the easternmost stake

had advanced $12\frac{3}{4}$ inches, and the westernmost stake $12\frac{1}{6}$ feet, making a **total expansion** of the ice in a distance of 500 feet of not less than 13 feet $2\frac{3}{4}$ inches in forty days.

Again, suppose we take an iron tube A and fill it with water, tightly closing it up by a screw stopper B (Fig. 107).

FIG. 107

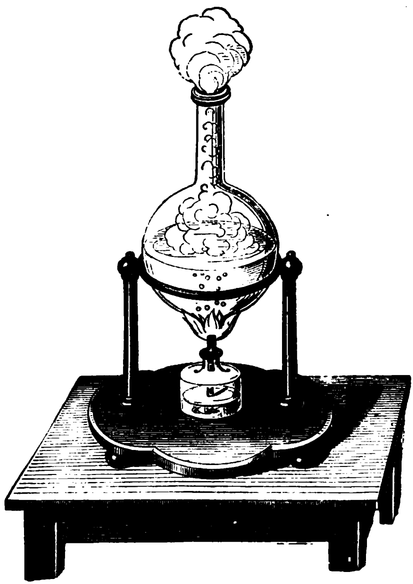


Bursting of iron tube by expansion of water in freezing.

Surround the tube with a freezing mixture of snow and salt. After a short interval the tube is rent, accompanied by a loud report.

This also is another illustration of the **expansion of water** during freezing, and will answer well for a class experiment.

FIG. 108.



55. **Liquids are converted into gases and vapours under the influence of heat.** The second effect of heat upon a liquid is to change its state.

As *solids* are converted into *liquids*, so are *liquids* converted into *gases* or *vapours* by heat.

We shall not have far to seek for an example of this.

A kettle or saucepan containing water if placed upon the fire will soon become empty. Why?

When a liquid is heated at the bottom (Fig. 108), small bubbles of vapour begin to rise, but before they reach the surface they are condensed.

This causes what is known as the *singing* of the kettle.

After a time, however, these bubbles find their way to the surface and burst, dispersing themselves in the air.

This **bubbling up** is known as **ebullition**, a word derived from the Latin (*ebullio*, I boil).

It is well that we should call the attention of the young reader to a word which denotes very much the same kind of action.

The word **evaporation** (which is derived from the Latin *evaporo*, signifying, I disperse in vapour) may be distinguished from **ebullition** by the formation of vapour *upon the surface* of the liquid, while in the latter case *the vapour* is formed *in the body* of the liquid itself.

Many are the illustrations which can be given of the conversion of a *liquid* into a *vapour* long *before* it reaches its boiling-point.

Let us take *water*, *ether*, and *alcohol* as examples.

I pour a small quantity of *ether* upon the back of my hand. How quickly it disappears! What has become of it? The heat of my body is sufficient to convert it into vapour.

Or, if we pour the same quantity of alcohol into a saucer this also will disappear from our natural view, although after a much longer period.

We say from our *natural* view, because many vapours may not be visible to the naked eye, and yet *may be seen* if looked at through a powerful glass.

Astronomers are often compelled to leave our islands and seek a climate where there is less moisture in the atmosphere to make their observations of the celestial world; the moisture or vapour in the air barring the view of the object under observation.

But the most important of all, and which affects us mostly, is the slow conversion of water into vapour ere it reaches its boiling-point.

We account for the formation of *fogs* and *clouds* by the quantity of *vapour* continually rising from the surface of seas, lakes, rivers, and oceans, which, being less dense than air, rises into the upper regions of the atmosphere, there **to condense** into drops and fall in the form of rain.

As before stated, *vapours* of colourless liquids, such as water, are also colourless, and therefore invisible; so that it is a

common mistake to say that we see ***steam*** issuing from the spout of a tea-kettle.

A careful observer will have noticed that what he calls steam is ***not seen close*** to the spout, but at a short distance away from it.

Steam is *invisible*; the cloud which we call steam arises from the condensation of the steam into minute watery particles, which remain suspended in the air.[1]

Among some of the results arising from the conversion of liquids into vapours by heat, we might mention the *crackling* of *wood* in a fire, and the *bursting* of a *chestnut* when placed upon the bar to roast.

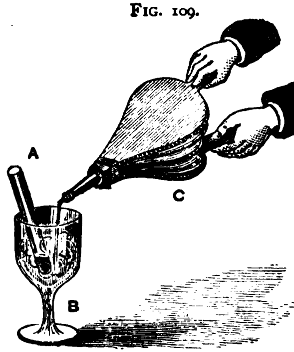
The moisture contained in the pores of the wood or of the chestnut is converted into vapour of great elasticity, which, while endeavouring to expand, drives the particles far and wide, unless some provision is made for their escape.

Boys usually prevent the splitting of the chestnut's skin by pricking it all over with a pin before placing it in front of the fire.

56. **Cold due to evaporation.**—In the paragraph just concluded we had occasion to speak *of the change* of a liquid into a vapour by the process of **evaporation.**

We now proceed to show that whenever a liquid **evaporates** very quickly **great cold** is produced.

FIG. 109.



Freezing by evaporation of ether.

I take a test-tube A, Fig. 109, containing water and place it in a wineglass B, at the same time surrounding the test-tube with ether.

If now a stream of air be forced through the ether by means of an ordinary pair of bellows C, the ether will evaporate so quickly that the water within the test-tube will become a solid mass of ice.

The reason for this is clear.

Heat is required to **evaporate** any liquid; consequently

[1] Ganot, *Nat. Phil.*, page 255.

the ether, **in evaporating,** absorbs or takes away the heat out of the water within the test-tube.

Advantage is taken of this by sailors travelling in hot climates. A porous jar having been filled with fresh water, it is surrounded by a wet stocking, and then hauled up into the rigging to dry.

By the evaporation of the water contained in the stocking heat is withdrawn from the water within the jar through its pores, thus rendering it icy cold for drinking purposes.

This explains why we feel cold when we come out of a bath, or out of the sea.

The skin being wet, heat will be taken from the body to convert the moisture into vapour.

It also explains the danger attending the sleeping in damp sheets; the sheets feel cold because they withdraw from our bodies heat sufficient to change the water left in them into vapour.

And, lastly, to cool the streets in summer watering-carts go round and sprinkle the roads, whereby cold is produced through the rapid evaporation of the water on the ground.

57. **Viscous liquids become mobile under the influence of heat.**

There is yet one other effect of heat upon a liquid which we ought to mention before closing the chapter.

The words **viscous** and **mobile** have already been explained in connection with the rates with which different liquids move when being transferred from one vessel to another.

Now, the most **viscous** liquid you can think of will become exceedingly **mobile** under the influence of heat.

A boy goes, in the winter, into a grocer's shop for a pound of golden syrup, and remarks what a long time it takes to run out of the can into his basin.

On reaching home he places the basin into the oven for a few minutes. What effect has it had upon the syrup?

It may now be poured out just as easily as water; in other words, a **viscous** liquid has become quite **mobile** under the influence of heat.

Similar effects can be witnessed by heating *glycerine*, *coal-tar*, and other **viscous** liquids.

QUESTIONS UPON THE TENTH CHAPTER.

Ques. 1. Describe a thermometer, and explain its action.

Ques. 2. What instrument is used for measuring heat? How is this instrument constructed?

Ques. 3. On one morning the thermometer shows $5\frac{1}{2}$ degrees below freezing-point, and in the afternoon it has risen 14 degrees. What is the temperature above freezing-point?

Ques. 4. What effect has heat upon *viscous* liquids?

Ques. 5. What is evaporation? Mention some liquids that evaporate quicker than water.

Ques. 6. Explain carefully why water pipes burst in frosty weather.

Ques. 7. A cubic foot of water has been converted into ice. What changes has it undergone?

Ques. 8. A chestnut put to roast on the fire suddenly explodes. Why is this? How could you prevent this?

Ques. 9. What do you mean by the *maximum density* of water?

Ques. 10. Mention any experiment you have seen to prove that liquids *expand* by heat.

Ques. 11. A saucepan filled with water is placed upon a fire, and long before the water boils it is observed to run over into the fire. Account for this.

Ques. 12. Mention the three different modes of graduating a thermometer. Would the *zero* of the *Fahrenheit* agree with the *zero* of the *Centigrade* scale?

Ques. 13. Describe an *alcohol* thermometer. On what occasions would you use an *alcohol* thermometer in preference to one filled with *mercury*?

Ques. 14. What is the difference between *ebullition* and *evaporation*?

Ques. 15. I pour *ether* and *water* upon the back of my hand; which *evaporates* first? Why?

Ques. 16. Describe fully the changes which take place when a cubic foot of ice originally 10 degrees below the freezing-point is continuously heated.

Ques. 17. Give a reason why wood gives off a crackling noise when placed upon the fire.

Ques 18. A bomb-shell, having been filled with water and plugged up tightly, was exposed to the severity of a Canadian winter. After a short time the plug was driven out with a great noise. State fully the cause of this.

Ques. 19. How would you explain the singing of a tea-kettle?

CHAPTER XI.

EFFECTS OF HEAT AND COLD UPON GASES AND VAPOURS.

58. Gases expand by heat and contract through cold—59. The air-thermometer—60. Cause of draughts—61. Ventilation—62. Cause of winds—63. Land and sea breezes—64. Condensation.

58. **Gases expand by heat and contract through cold.**—This is what we might have expected, seeing how true the statement is for solids and liquids.

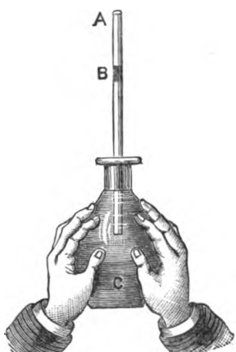
A bladder partly filled with air, if held in front of the fire, will soon appear full.

The air within, as soon as it is heated, **expands**; that is, its molecules try to get farther and farther apart, and in so doing completely extend the bladder.

If the bladder be then allowed to cool, **cold**, which is a word signifying the absence of heat, will cause the air within to return to its former dimensions—in other words, **to contract.**

59. **The Air-Thermometer.**—Another way of proving the expansibility of gases by heat is by the use of the **air-thermometer.**

FIG. 110.



In its simplest form it consists of a flask C, Fig. 110, with a piece of fine glass tubing passing through its cork. If a drop of ink be poured down the tube, and the flask be held between the two hands, it will be seen to ascend to the top of the tube A and eventually to flow over. The heat of the hand warms the glass, which very quickly communicates its heat to the air within, thus producing an **expansion** of the air; and since it is only free to expand in one direction, viz. *upwards*, the little drop of ink B is lifted up the tube by the expanding air.

Castelli, writing in 1638 to Ferdinand Cæsarina, says, 'I remember an experiment which Signor Galileo had shown me more than thirty-five years ago.

'He took a glass bottle D, about the size of a hen's egg, Fig. 111, the neck of which was two palms long and as narrow as a straw.

'Having well heated the bulb in his hand, he placed its mouth in a vessel E, containing water, and then, withdrawing the heat of his hand from the bulb, the water instantly rose in the neck more than a palm above the level of the water in the vessel.'

This is shown in Fig. 112, the liquid rising in the neck to the height of one palm, viz. to F, because the pressure of the

FIG. 111.

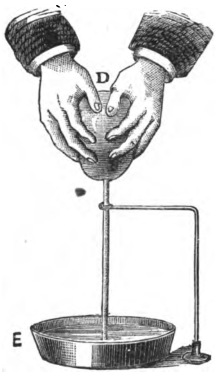
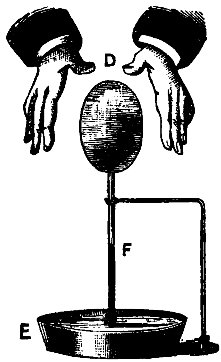


FIG. 112.



air without is greater than the pressure of the air left in the bulb.

Similar results would be obtained if we were to fill the flask with hydrogen gas or oxygen gas.

60. **Cause of draughts.**—One of the first consequences resulting from the expansion of a gas is its diminished density; that is, a gas which has been heated weighs less than it did before, taking bulk for bulk.

This being so, a *warm* gas will try to ascend until it meets with a layer of its own density.

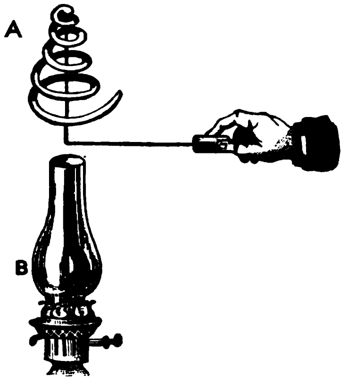
It is through this cause that air which has been expanded by heat rises to the top of a room; likewise the **draughts** in chimneys are created through the same cause.

The air in a room, being heated by the fire within the grate, rises in the chimney in proportion to the expansion of the

air. Hence there is a rush of cold air across the room towards the fireplace, to take the place of the air which has ascended.

This, then, is the theory of all **draughts**: the air being heated, naturally **expands**, which has the effect of reducing its density, and, being of less weight, bulk for bulk, than cold air, it rises, and is replaced by air of greater density.

FIG. 113.



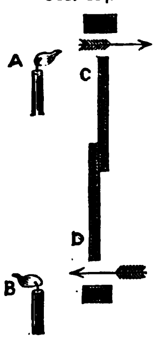
A very amusing experiment in support of the ascent of warm air is performed by a piece of cardboard cut in the form of a spiral.

When held over the flame of a lamp, the force of heated air ascending will cause the spiral to turn round rapidly, if lightly balanced.

In Fig. 113 a piece of cardboard A, cut in a form of a spiral, is held over the hot air ascending from the lamp B, with the result just stated.

We sometimes speak of the **draughts** coming from a window. This is occasioned by a rush of cold air from the outside through the crevices around the sill, to balance the pressures of the air within and without the room.

FIG. 114.



61. **Ventilation.**—By this we mean the freeing of a room or mine of its impure air, by the creation of a draught.

In a room which is closed, the air on being heated **expands**, rises to the ceiling, and is there got rid of by the opening of the top sash.

Similarly, by raising the bottom sash, a fresh supply of pure air is admitted to take the place of that which has passed out. The truth of this statement can be tested by bringing a lighted taper or candle close to the openings at the top and bottom of the window.

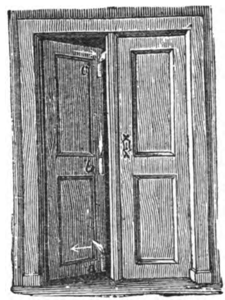
At the top (Fig. 114) the flame is observed to be blown

outwards, showing that a current of air is passing in that direction, while at the bottom the flame is driven **inwards.**

The same results would be obtained by opening the door of a warm room, and by placing a lighted candle in *three* different positions.

When at the top of the doorway the direction of the flame indicates the existence of a warm current of air moving **outwards**, as shown at *c*, Fig. 115.

FIG. 115.



If placed near the floor the flame is blown **inwards**, thus showing a current of air moving in the opposite direction.

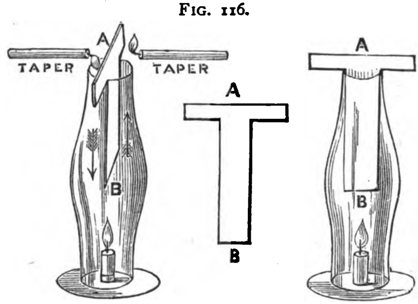
This is shown by the direction of the arrow at *a*. When, however, the candle is held midway, the flame burns perpendicularly as at *b*, it not being influenced by any air-current whatever.

Another interesting class experiment is performed by burning a candle within an ordinary lamp-glass, which has been divided into two sections by a piece of tin plate cut in the form of a T-square.

In Fig. 116 two views of this arrangement are given.

When a lighted taper is brought near to the top of the lamp-glass to the right of the tinplate A B, its flame is blown **upwards** by the ascending current of warm air.

FIG. 116.



If held to the left of the plate A B the flame is blown **downwards**; at the same time a quantity of smoke is taken down the glass by the in-rush of cold air.

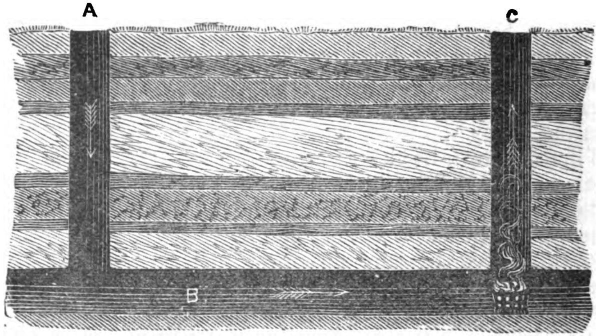
This brings us to the question of the **ventilation** of mines.

Two shafts are sunk, sometimes a mile apart. At the

bottom of one of the shafts a fire is kindled (Fig. 117), thus creating an **upward current** of air.

To replace this ascending current of warm air, a large quantity of cold air rushes down the other shaft, along the tunnel until it reaches the bottom of the up-shaft, there to be heated and to ascend like that which preceded it.

FIG. 117.



Section of a coal-mine.

Before leaving this question, it is well that we should point out some of the ill effects arising from insufficient ventilation.

In visiting one of the schools in Bethnal Green, the writer was forcibly reminded of the ignorance prevailing upon this subject.

In a very small room lived a man, his wife, and six children.

The weather was cold and the room draughty, and to check the draughts the crevices around the windows had been carefully covered up by pasting brown paper over them.

The chimney was nicely packed with old sacks; nor did they forget to list the door.

Before retiring to rest a coke fire was brought in and placed upon the hearth, the door was shut, and all lay down to sleep.

In the morning, on awaking from his slumbers, the father discovered one of the children to be dead.

The cause of death is not far to seek—suffocation through inhaling impure air.

What lesson may we learn from it? Is it not that it is far better to suffer a draught to exist in our bedroom rather than run the risk of being poisoned by breathing impure air?

62. **Cause of winds.**—The expansion and contraction of the air brought about by the action of the sun's heat forms one of the principal **causes of wind.**

The layers of air in close contact with the earth's surface, being very hot, **expand**, and consequently rise by virtue of their lightness; while those layers in the higher regions of the atmosphere, being much colder and denser, fall to take their place.

Again, the earth rotating upon its axis once every twenty-four hours is another important **cause of wind.**

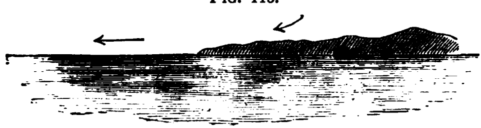
Sir Charles Lyell, in his work on geology, relates a curious phenomenon, showing the existence and power of **currents** and **counter-currents** in the air, as was observed during the eruption of a volcano in the island of St. Vincent in 1812.

Though the trade-wind continually blows from Barbadoes to St. Vincent, yet ashes thrown to a great height were carried from St. Vincent to Barbadoes.

In 1815, during the eruption of Sumbawa, in the island of that name, ashes were borne to the islands of Amboyna and Banda, 800 miles distant from and east of the site of the volcano, and during the height of the south-east monsoon.

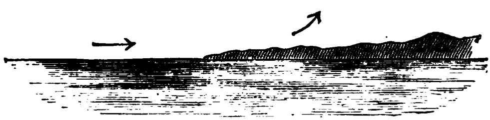
63. **Land and sea breezes.**—The consideration of the various kinds of winds is a very wide subject, altogether outside the scope of this little book; nevertheless it may not be out of

FIG. 118.



Land breeze by night.

FIG. 119.



Sea breeze by day.

place to consider the question of **land and sea breezes,** 'when the wind bloweth in from the sea.'

During the day the *land* becomes more heated than the

sea, consequently the air over the land is warmer than the air over the sea. What follows?

The air over the land *ascends*, and is replaced by a current of cold air flowing **from** the *sea* to the *land*.

This constitutes a **sea-breeze**.

Again, during the night the land parts with its heat sooner than the water does.

Hence the air over the land is colder than the air over the sea, and, as the current of air is always **from** the colder to the warmer layer, a **land-breeze** is produced.

64. **Condensation.**—This is an expression used to denote the return of a *vapour* or *gas* to the *liquid* state.

As we usually understand the word, it gives us the idea that the body has been made to occupy less space. And so it is.

Steam, when **condensed** into the state of water, occupies only $\frac{1}{1700}$th part of the space which it occupied when in the form of a gas.

There is every reason to believe that all *gases* are in reality *liquids* in the form of *vapour*.

Many of them, by being subjected to great pressure in a wrought-iron receiver by means of a force-pump, can be liquefied. Of course, when the liquid is taken out of the receiver and relieved of the enormous pressure under which it existed, it immediately endeavours to go back to its gaseous state.

It is in a tremendous hurry to do this, and as it is unable to become a vapour without it receives a large increase of heat, it compels all the surrounding bodies to deliver up their heat.

Laughing-gas so condensed, under a pressure of 450 lbs. on every square inch, when liberated can produce a temperature of nearly 200 degrees below the freezing-point of water by its rapid evaporation.

If the experiment had been performed under the receiver of an air-pump, as low as 300 degrees below freezing-point would be reached.

Nature supplies us with many illustrations of **condensation**.

In heated rooms the windows often become covered with moisture. Why is this?

The glass, being colder than the air in immediate contact with it, **condenses** the aqueous vapour contained in the air.

Similar effects are witnessed when a glass of cold water is

suddenly taken into a warm room : a deposit of dew is seen on the outside of the glass.

Perhaps the most perfect illustration afforded to us by Nature is the formation of **rain.**

The vapour which is formed from the surfaces of rivers and seas being of less density than the air, naturally rises into the higher regions of the atmosphere, there to be **condensed** into very small drops of water.

Lastly, the formation of **dew** also points to the restoration of *aqueous vapour* to its former state by the process of **condensation.**

QUESTIONS UPON THE ELEVENTH CHAPTER.

Ques. 1. What is condensation? Give some examples from Nature.

Ques. 2. Describe an *air-thermometer*. What serves the purpose of an index?

Ques. 3. State fully the cause of the *land* and *sea* breeze.

Ques. 4. How is a rain-drop formed?

Ques. 5. In ventilating a room, why do you open both the top and bottom sashes of a window?

Ques. 6. State in full what you know of the formation of winds.

Ques. 7. Give an experiment to prove that gases expand when heated.

Ques. 8. State the usual plan of ventilating a mine.

Ques. 9. What methods have been employed to convert vapours and gases into liquids by mechanical contrivances?

Ques. 10. A lighted candle is held in the open doorway of a room which contains a fire. State what effect it will have upon the flame of the candle when it is held near the top and also when near the bottom of the door.

Ques. 11. How do you account for the whistling of the wind around the frames of a window?

Ques. 12. A bladder half filled with air is held before a blazing fire. State fully what appearance the bladder will present after a short time.

Ques. 13. Gases expand by heat and contract by cold. Give two experiments to prove this.

Ques. 14. How would you explain the draughts felt when sitting near an open window?

Ques. 15. Sketch and describe any method you are familiar with for ventilating a room by means of openings in the ceiling.

Ques. 16. State the two *principal* causes in the formation of wind.

Ques. 17. What effect will be produced upon a gas by compressing it into a very small space?

Ques. 18. Give as many instances as you can of *condensation* from Nature.

Ques. 19. How is dew deposited?

Ques. 20. In dwelling-houses the painted walls are often coated with moisture. How do you explain this?

CHAPTER XII.

PRESSURE OF THE AIR.

65. **Pressure of the air upwards.**—We shall endeavour throughout this chapter to point out how *solids*, *liquids*, and *gases* differ in the matter of communicating pressure which has been previously applied to them.

Take, for example, *a table*: you press upon it downwards; none of the pressure you exert will be transmitted horizontally, for the whole will be felt in the line of action.

Again, I fill a can with water: upon the bottom a certain pressure will be felt, as also upon its side, and this in proportion to the depth of water; but when we come to deal with *gases*, of which the *air* will furnish us an example, we shall observe quite a different state of affairs.

In a room the **pressure of the air** upon the ceiling **upwards** is just the same as upon the floor **downwards**; and the pressure upon any one wall **horizontally,** per square inch, is the same as upon another adjoining it.

FIG. 120.

As the working of so many different pieces of apparatus depends upon the principle that the air presses **equally** in all directions, we propose to examine this question very minutely.

First.—We say the **air presses upwards.**

To prove this experimentally we take an ordinary glass tumbler (Fig. 120) and fill it to the brim with water.

If now a stiff piece of cardboard be placed upon the top and the tumbler be turned upside down, the water will *not* run out. Why is this?

The water is kept within the glass by the **upward** pressure of the air against the cardboard, the pressure being **much** greater than the weight of water within the tumbler.

A second experiment very amusing to boys is performed by taking a tin can with a number of small holes in its bottom.

When the can is dipped into a pail of water it will fill; upon being lifted out, however, the water remains inside as long as the thumb is kept over the mouth of the can.

Here we perceive a body of water supported by the **upward** pressure of the air; for as soon as the thumb A is removed from the mouth of the can and the air admitted to it the water rushes out, as shown in Fig. 121, it being then acted upon by

FIG. 121.

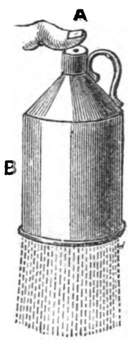


FIG. 122.

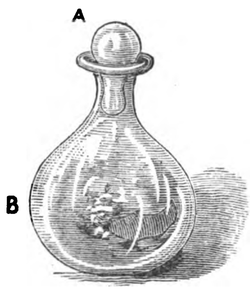


FIG. 123.

the **downward** pressure as well as by the **upward** pressure of the air.

66. **Pressure of the air downwards.**—This is proved in many ways. We proceed to give a few.

Light a piece of brown paper (Fig. 122), and plunge it into a water-bottle B containing air.

When the paper has been burning a short time, close the mouth of the bottle by means of a hard-boiled egg A, which has been previously stripped of its shell.

The burning of the paper has caused a partial vacuum within the bottle, consequently the egg is gradually forced *inwards* by the **downward** pressure of the air.

Again a common plan of proving the same thing is for a boy to place his hand over the narrow end of a glass vessel, Fig. 123,

which stands upon the plate of an air-pump, and then to pump all the air out of the vessel.

He very soon realises that there is some force keeping his hand down tightly against the glass, which is none other than the **downward** pressure of the air.

Or we might have used another glass vessel, Fig. 124, substituting for his hand a piece of pig's bladder stretched tightly across.

So long as the air is left inside the glass nothing happens; but directly we begin to pump the air out, the bladder grad-

FIG. 124.

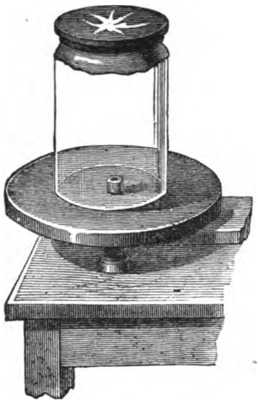
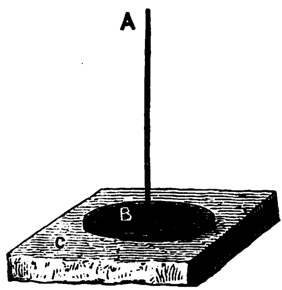


FIG. 125.



ually assumes a saucer-like appearance, and finally bursts with a loud report.

This is also explained by reference to the **downward** pressure of the air upon the bladder.

Boys often amuse themselves with a *sucker*, Fig. 125, which consists of a round piece of stout leather B with a string A passing through its centre.

The leather having been wetted, it is placed over a flat stone and then stamped upon by the feet.

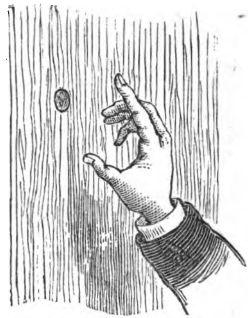
On pulling the string up they find that the stone adheres to the leather.

This can only be explained by assuming that all the air between the leather and the stone has been squeezed out, and

that the **downward pressure** of the air keeps the leather against the stone.

67. **Pressure of the air sideways.**—Take a coin and press it against the side of a bookcase, carefully rubbing the coin for a short time against the wood to disperse any air which may be left between their two surfaces.

FIG. 126.

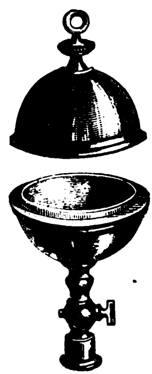


On removing the fingers the coin will remain, the pressure of the air **horizontally** being sufficient to keep it in its place.

68. **Pressure of the air in all directions.**—To test the truth of this, we cannot do better than employ the Magdeburg Hemispheres, which are so named from the town where they were first used.

Otto von Guericke, of Magdeburg, in 1654 selected two hollow hemispheres of brass, which fitted each other with great nicety.

FIG. 127.



The diameter of the sphere he used was nearly a foot, and it was provided with a stop-cock by which communication could be shut off when screwed on to an air-pump.

This is shown in the lower half of Fig. 127. Rings also were provided, by which two persons could lay hold of the two hemispheres.

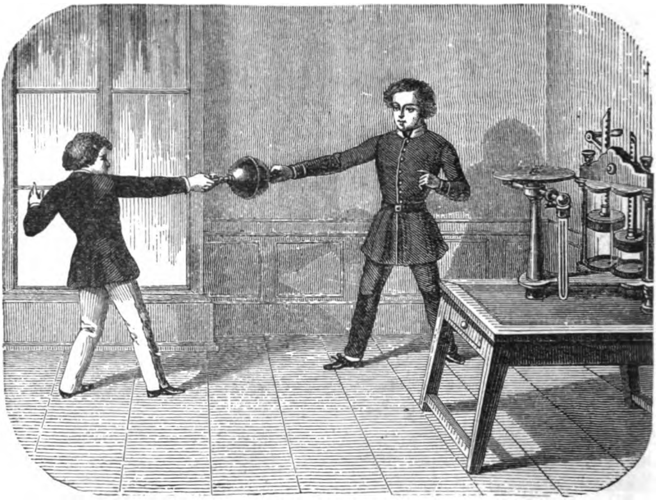
So long as the air remained inside there was no difficulty in pulling the hemispheres apart; but when the air had been taken out the pressure of the surrounding atmosphere **on all sides** was so great that the hemispheres could not be drawn asunder, even though horses were harnessed to the two rings attached to them.

That this is true every boy will admit who has seen his comrades in class tugging away at them with all their might, as depicted in Fig. 128.

69. **The Air-pump.**—Mention has been made several times throughout the chapter of the air-pump, the construction of which we now proceed to describe.

The inventor was Otto von Guericke, of Magdeburg, whose name has already been mentioned in connection with the Magdeburg Hemispheres.

FIG. 128.



Since his day many modifications have been introduced, more particularly with respect to the valves and the mode of working it.

As now constructed by Tate, we have simply a cylinder fitted at each end with oiled silk valves, and two solid pistons worked by a single piston-rod.

As depicted in Fig. 129, the barrel A B represents a brass cylinder 16 inches long, with a bore of $1\frac{1}{4}$ inches diameter.

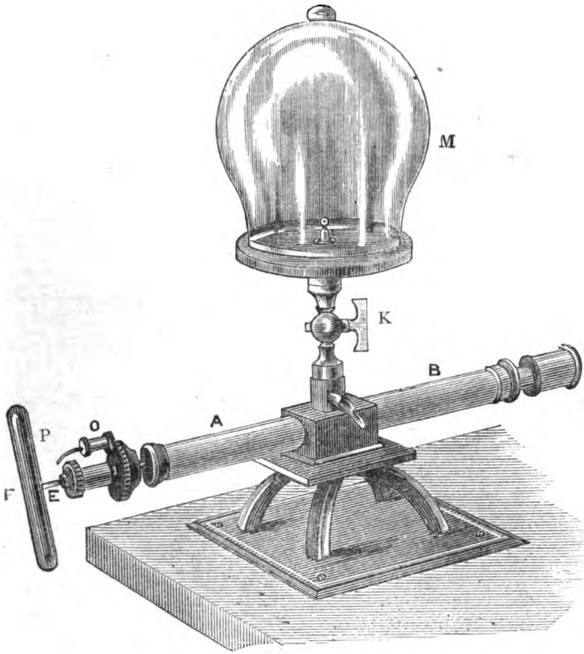
It contains two pistons C and D, which can be seen to greater advantage in Fig. 130, the two being attached to the piston-rod E, and worked by means of the handle F.

At the end of the barrel N there is a small hole, over which is stretched a piece of oiled silk, which acts as a valve to prevent the air from returning into the barrel after it has been forced out.

Also at the other end of the barrel O there is a hole,

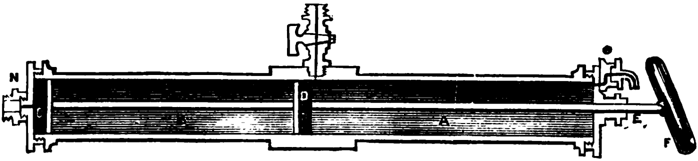
covered by a similar valve of oiled silk, the whole being enclosed in a cap, containing the bent pipe P.

FIG. 129.



Lastly, midway between the two ends of the barrel a stop-cock K is fitted (Fig. 129), so as to open or shut off

FIG. 130.



communication between the inside of the barrel and the receiver M.

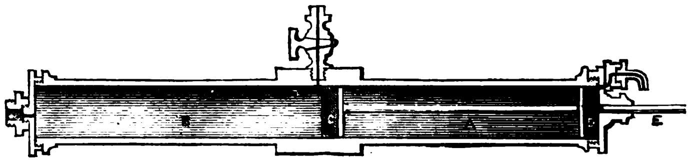
I 2

When about to work the pump we clamp it firmly to the table, or provide it with a substantial bed-plate, so that in moving the pistons to and fro there may be no danger of the receiver M falling off.

When the pistons are in the position shown in Fig. 130, there is a communication between the receiver M and one half of the barrel A.

On pulling the handle F towards you, the pistons take up the position shown in Fig. 131, leaving the other half of the barrel B in communication with the receiver.

FIG. 131.



By this act all the air between the piston D and the end E is forced out through the valve at O; also the air which has escaped from the receiver into that portion of the barrel marked B can now be forced out through the valve at N during the next return stroke of the piston.

Hence during both the forward and backward strokes of the pistons air is forced out at either end of the barrel.

This is but a very brief account of the air-pump, the writer believing that where it is possible opportunities should be afforded to the class to examine for themselves the construction of the pump, whereby they may learn more in five minutes than by an hour's reading from a text-book.

70. **The Barometer.**—All that has been said in the former part of the chapter simply demonstrates the existence of atmospheric pressure. The question now arises, what methods have been adopted to determine the exact amount of this pressure?

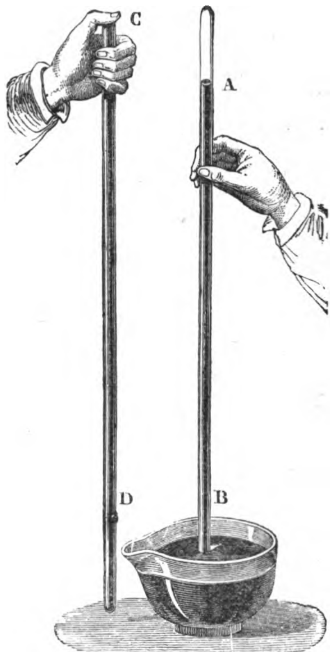
Torricelli, a pupil of Galileo, in 1643 performed a very simple experiment by taking a glass tube about 36 inches long, which was closed at one end and open at the other, and filling it with mercury.

When he had placed his finger over the open end C (Fig. 132), he turned it upside down and lowered it into a cup of mercury;

as soon, however, as he removed his finger the mercury fell to the point A, and there remained, which on measuring was found to be about 30 inches from the surface of the mercury in the cup.

Pascal, who desired to satisfy himself that the force which kept this column of mercury from falling was really due to the downward pressure of the air upon the surface of the mercury in the cup, repeated Torricelli's experiment in the year 1646, ascending one of the mountains in Auvergne for that purpose.

FIG. 132.



There he found that the height of the mercurial column was only 27 inches; the difference between the two heights he attributed to the weight of a less quantity of air which pressed downwards upon the mercury in the cup.

Aeronauts who have ascended as high as 21,460 feet above the level of the sea tell us that the mercury in the tube stands at 13 inches, while Messrs. Coxwell and Glaisher at Wolverhampton found that on ascending to the height of 29,000 feet the mercury stood as low as $9\frac{3}{4}$ inches. Since then the experiment has been tried by filling a tube about 35 feet long with water, at the same time inverting it over a tank of water.

In that case the water remained at the height of 34 feet above the level of the water in the tank.

Now, if we compare the weight of mercury with the weight of an *equal volume* of water, we shall have the same relation existing between them as exists between the heights of the *water* and *mercurial* columns, viz. 13·6; from which we conclude that

the weight of a column of mercury 30 inches in height, or the weight of a column of water 34 feet high, may be looked upon as a measure of the pressure of the air upon a surface equal to the internal area of the tube.

Now if in Fig. 133 we assume this internal area to be one

FIG. 133.

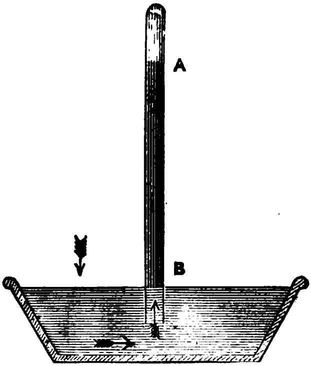
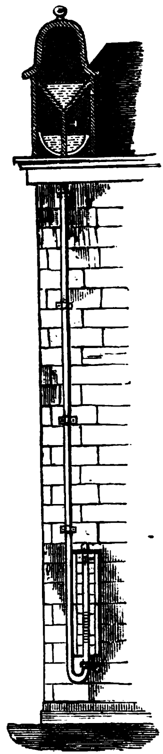


FIG. 134.



square inch and the height A B to be 30 inches, it will be evident that 30 cubic inches of mercury are supported by the pressure of the air, which in the first instance acts *downwards*; and since liquids transmit pressure in all directions, this *downward* pressure is passed on, as shown by the arrows in the cut, until the weight of 30 inches of mercury is kept from falling by an *upward* pressure equivalent to the atmospheric pressure.

This column of 30 cubic inches of mercury having been weighed, gives 14·7 lbs., or nearly 15 lbs., as the amount of atmospheric pressure upon one square inch.

This leads us to the question as to the name given to instruments which register the amount of atmospheric pressure.

The Greek language supplies us with two words—*baros*, signifying *weight*, and *metron*, a *measure*.

Hence the word **barometer** is introduced into our language as the name of the instrument that *measures* the *weight* or *pressure* of the air.

Already we have mentioned that *water* has been used in filling a barometer tube.

In the accompanying sketch (Fig. 134) a leaden pipe is seen fixed against a house, its length being about 35 feet.

On the top is a funnel furnished with a stop-cock and placed in a tank of water.

The lower part of the tube is bent, and a glass cylinder is attached to it—the glass being about 3 feet long—which is likewise graduated.

There is also a stop-cock at the junction of the leaden and glass tubes.

With regard to its action, the lower stop-cock having been shut, water is poured into the funnel until the leaden pipe is full.

The stop-cock at the top is then shut and the lower one opened, when the water will be observed to fall slightly, leaving a vacuum in the top of the tube.

If we then measure the vertical distance between the two surfaces of the liquid, we shall at the sea-level find the height to be about 34 feet.

The fact of the short arm being of glass enables us to observe the rise and fall of the water within, thus showing that the pressure of the air varies from day to day.

This arrangement is termed a **water barometer.**

Further, what are the several *uses* of the **barometer?**

First.—It is employed to calculate the heights of mountains; for, if a **mercurial barometer** at the sea-level stand at 30 inches, it will register less on the mountain-top, because the height of the atmosphere there is less than at the level of the sea, and consequently exercises less pressure, thereby producing a fall of the mercury in the barometer tube.

It is rather difficult to state a rule whereby we may conclude the exact height we have ascended: for small elevations we shall not be far wrong if we reckon 900 feet for every fall of one inch in the mercurial column.

Secondly.—Another important use to which the **barometer** is put is to ascertain the probable weather we are likely to have for the next twenty-four hours.

Air charged with watery vapour is *lighter* than dry air

hence a fall of the mercury in the tube indicates a certain amount of watery vapour in the air, which if it were to condense would form rain.

Ganot, in his popular work on 'Natural Philosophy,' gives us the following table from direct observation :—

Height	State of the weather
31 inches	Very dry
$30\frac{2}{3}$,,	Settled weather
$30\frac{1}{3}$,,	Fine weather
30 ,,	Variable
$29\frac{2}{3}$,,	Rain or wind
$29\frac{1}{3}$,,	Much rain
29 ,,	Storm

In the daily papers we read that a south-west wind is an indication of rain, and a north-easterly wind may be considered a forecast of fine weather.

The south-west wind, in coming to us from the equatorial regions, passes over vast tracts of water and thus becomes charged with a great deal of moisture, which on being condensed produces rain.

On the other hand, the north-easter, in traversing immense tracts of dry land in central and northern Europe, parts with any watery vapour it may contain, and therefore reaches us as a drying and shrivelling wind.

Lastly, a *sudden* rise or a *sudden* fall of the **barometer** is a sure sign of bad weather ; for then there is some local disturbance, or else the atmosphere is becoming rapidly charged with aqueous vapour.

QUESTIONS UPON THE TWELFTH CHAPTER.

Ques. 1. What do you mean by atmospheric pressure? Show that the atmosphere presses on a body, and to what amount.

Ques. 2. Give an example to show that air has an upward pressure. What is the amount of this pressure?

Ques. 3. Describe a *sucker*, and explain why it can lift a stone.

Ques. 4. Draw a diagram of an *air-pump*.

Ques. 5. If we suck one end of a straw, the other end of which is placed in water, why will the liquid rise into the mouth?

Ques. 6. Describe an experiment showing the upward pressure of the atmosphere.

Ques. 7. Explain the following experiment: A tube partly immersed in ink, with the finger placed on the top, is raised, when the ink *remains* in the tube; but when the finger is removed from the top the ink falls out.

Ques. 8. What supports the mercury in a barometer tube?

Ques. 9. Why does the mercury in a barometer fall on being carried up a mountain?

Ques. 10. What does a barometer show, and what use is made of it?

Ques. 11. Show by an example that the weight of air differs according to its condition.

Ques. 12. Explain the action of the barometer as a weather-glass.

Ques. 13. Explain carefully why a sudden fall of the mercury in a barometer tube is considered to be a sign of approaching wet weather.

Ques. 14. Describe a barometer, and show how it may be used in measuring heights.

Ques. 15. What is a *water barometer*? About what length of tube should we require to make a water barometer?

Ques. 16. What do you mean by a Torricellian tube? Explain fully.

Ques. 17. Sketch and describe the *Magdeburg Hemispheres.* What kind of pressure is illustrated by them?

CHAPTER XIII.

ATMOSPHERIC PRESSURE APPLIED.

71. The syringe—72. The syphon—73. The suction or lifting pump—74. The force-pump—75. The bellows.

71. **The Syringe.**—This is a well-known piece of apparatus, and one which most boys know how to use.

Its construction is very simple, consisting of a hollow cylinder tapered off to a point, except when used for watering a garden, in which case the end is flat and full of tiny holes.

Inside works a solid piston, which generally consists of leather or worsted wrapped round a cylinder, either of glass or of some metal.

The piston being at the extreme end of the barrel, viz. at A (Fig. 135), a very small quantity of air is left in the syringe between the piston and the surface of the water in the tank C.

As soon, however, as the piston is drawn to the other end of the barrel, viz. to B, this small quantity of air expands and fills the whole barrel; but gases, when they expand, are not able to press with the same force, and consequently the pressure of the air within the barrel is less than the pressure of the air downwards upon the surface of the water in the tank.

What follows from this?

The water in the tank C being acted upon by two forces, one of which is greater than the other, it naturally goes in the direction of the greater force, and is consequently driven into the barrel of the syringe, viz. by the external pressure of the air.

When the syringe is lifted out of the tank the water does not attempt to run out. Why?

The pressure of the air upwards is much greater than the weight of the water within; it therefore remains suspended until driven out by a force applied at the end of the piston-rod.

FIG. 135.

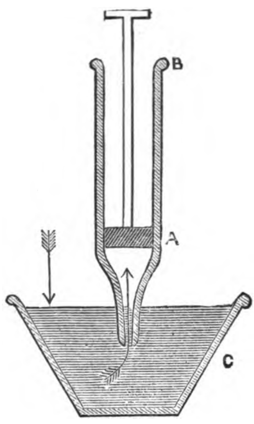
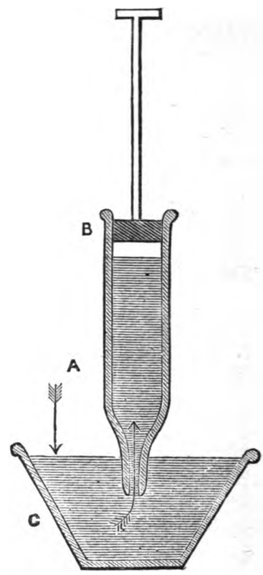


FIG. 136.



In Figs. 135, 136 the piston is shown at both ends of the barrel, before and after the water has entered; the two arrows in each figure denoting the atmospheric pressure upon the surface of the water, and its consequent effect in driving the water into the barrel.

72. **The Syphon.**—The **syphon** is a piece of bent tubing, having one arm longer than the other.

Its chief use is to transfer liquids from a higher to a lower level.

To understand its action, suppose we take a piece of glass tubing B A C, Fig. 137, with equal arms, and fill it with water.

Place two pieces of cardboard over the open ends, and then turn it upside down carefully.

Now, if the tube be of uniform bore throughout, it is evident there will be the same quantity of water in the one arm as in the other.

The water in both arms will therefore remain suspended by the upward pressure of the air against each end.

FIG. 137.

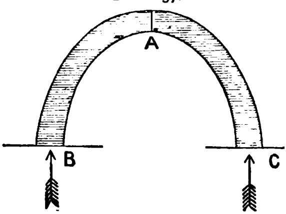
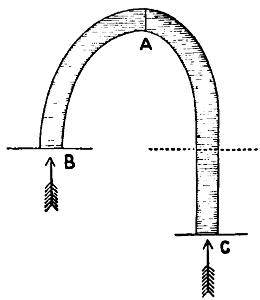


FIG. 138.



Suppose, however, we have a tube bent with arms of unequal length, as shown in Fig. 138, then the weight of water in the one arm will be greater than the weight of the water in the other; and although the upward pressure of the air may be the same at B as it is at C, nevertheless the water runs out at the end of the longer arm A C.

This is easily explained.

The upward pressure required at C to prevent the water from running out must be equal to the weight of the water in the arm A C, together with the pressure of the air at B.

Similarly, the pressure of the air upwards at B to prevent the water from running out must be equal to the weight of the water in the arm A B, together with the pressure of the air upwards at C.

A moment's reflection, however, will show that the pressure of the air upwards in the one case *would have to be* greater than

in the other, if the water remained suspended, which we know is not so.

Hence the water runs out from the longer arm by reason of the weight of water in it being in excess of that contained in the shorter arm, which flows faster in proportion to the difference between the lengths of the two arms.

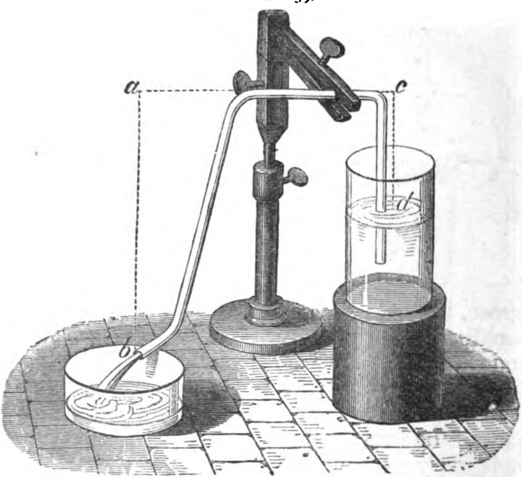
Many important questions arise in the working of the **syphon.**

First.—Is it possible for a **syphon** to be of any length we please?

The answer is—No.

For if we consider what takes place when a syphon is at work, we shall be satisfied that there is *a limit* beyond which it will not act.

FIG. 139.



In turning to Fig. 139, we observe the water running out of the lower end *b*.

This naturally leaves an empty space in the upper part of the tube, which is refilled by water from the cylinder *d*, through the downward pressure of the air, which acts upon the surface of the water sufficient to raise and support a column of water 34 feet in height.

If, therefore, the distance *c d* exceed this amount, the water

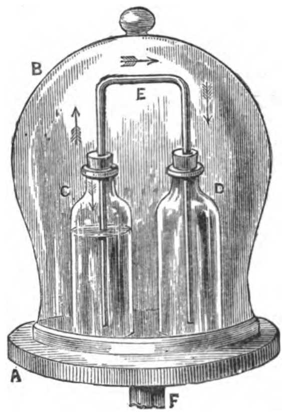
would not rise sufficiently high in the shorter arm to pass the bend.

Further, if the **syphon** were taken to the top of a mountain where the air is less dense, then the pressure of the air would not be equal to the weight of a column of water 34 feet high.

Hence a **syphon** at the sea-level would be able to work at a greater advantage than on the mountain-top.

In support of what has already been stated about the working of the **syphon**, the following class experiment will be found interesting.

FIG. 140.



Two bottles, C, D (Fig. 140), are fitted with corks through which passes the syphon E.

Water is poured into one of the bottles (C) sufficient to nearly fill it.

Through the cork in the neck of the bottle D a hole is bored, when the whole arrangement is placed under the receiver of an air-pump B.

The air having been taken out of the receiver B, that which is left within the bottle D will escape through the hole in the cork into the receiver, and in the next stroke of the pump will be forced out.

Thus a vacuum will be created within the bottle D.

Now observe what happens to the water in the bottle C.

The air within C, acting downwards upon the surface of the water, raises it up the pipe, along the bend E, and thence into the bottle D.

This is what takes place in every **syphon.**

In one way or another a vacuum is created at the top of the bend E; this vacuum is immediately filled by water rushing in, it having been driven there by the downward pressure of the air.

Of recent years a very important addition has been made to **the syphon.**

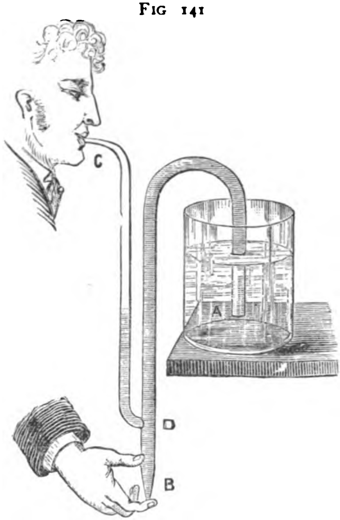
It consists of a suction-pipe C D (Fig. 141), which enters the longer arm at D.

The end A having been placed in a vessel of water, the mouth is applied to the upper end C.

Having closed the lower end B with the finger, the air is withdrawn by the mouth, when the water from the tank is seen to rise up the tube A, flow over the bend, and fill the mouthpiece C D.

No sooner is the finger removed from the end B than a continual stream of water rushes out, until the water in the vessel sinks to the end A and there remains.

FIG 141



73. The Suction or Lifting Pump.—This dates back as far as 130 B.C., when Ctesibius, the teacher of the celebrated Hero, of Alexandria, employed it for raising water.

It consists of four principal parts :—

First, the barrel.
Secondly, the piston.
Thirdly, the suction-pipe.
Fourthly, the valves.

In Fig. 142, B represents a piston within a glass cylinder, which we term the *barrel.*

At the top of the *suction-pipe* A is a valve S opening upwards; the piston likewise containing a valve O, to open upwards, to prevent the return of the water after it has passed through a hole in the piston.

In Fig. 143, an enlarged view of these two valves S and O is given.

P is the handle by which motion is given to the piston-rod C.

When the piston B is raised for the first time, a *vacuum* or *empty space* is produced between the piston and the bottom of the barrel ; the valve S is therefore raised by the air in the suction-pipe A in consequence of its expansive property.

Now, air that has expanded presses with less force ; consequently the pressure of the air within the tube is less than that of the air outside.

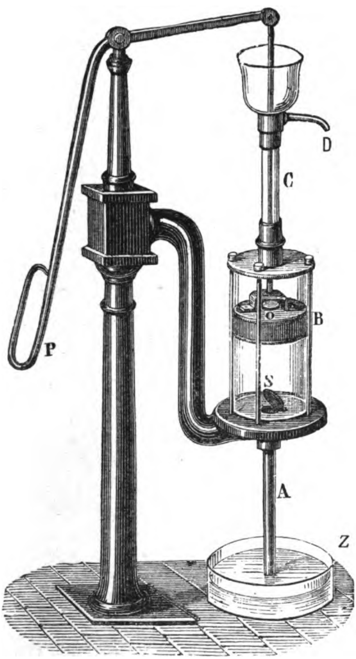
What follows from this?

The water from the tank Z rises within the suction-pipe A by reason of this difference of pressure.

In the first downward stroke of the piston the air which has escaped into the barrel from the pipe A through the valve S is compressed, which has the effect of opening the valve O, by which means it makes its escape into the barrel above the piston and thence into the open air.

In the second stroke upwards the water rushes through the valve S into the barrel, having been raised up the pipe A by the downward pressure of the air upon the surface of the water in the tank.

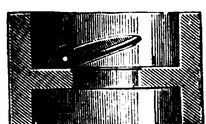
FIG. 142.



In the next down stroke the valve S closes, but the valve O opens, allowing the water which has been compressed to escape into the barrel above the piston.

This action is repeated in each successive stroke, provided that the length of the suction-pipe is less than 34 feet, which is the greatest height to which the atmosphere is able to raise a column of water.

FIG. 143



In practice, the suction-pipe is always less than 34 feet, as otherwise, the vacuum within the barrel not being quite perfect, a small quantity of air would prevent the water from ever entering the barrel.

One point should be carefully noted, viz. the water which escapes from the spout D is raised during the upward stroke, having been **lifted** up on the top of the piston.

Hence the reason why it is called a **lifting-pump.**

75. **The Force-pump.**—In this pump the water rises into the barrel in exactly the same way as in the **lifting-pump** ; but when there, it is raised to any given height according to the pressure exerted upon the piston.

In Figs. 144 and 145 we have two views of the interior of a **force-pump**, during the ascent and descent of the piston.

FIG. 144.

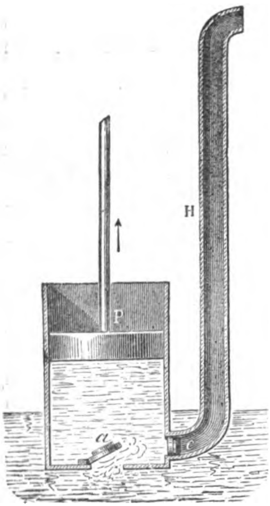
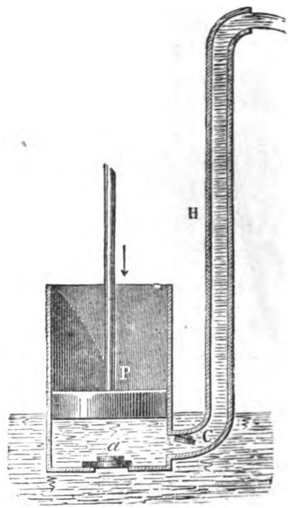


FIG. 145.



In Fig. 144 a solid piston P is shown ascending, with the valve *a* opening upwards, while the valve C is kept closed by the pressure of the air in the pipe H.

In Fig. 145 the piston P is seen descending, which has the effect of closing the valve *a* and of opening the valve C.

The water is therefore raised in the pipe H by the pressure applied to the piston-rod in its motion downwards.

The height therefore to which water can be raised by means of a **force-pump** has *no limit*, as is the case in the **lifting-**

pump; for according to the force applied, so will be the height to which it is raised.

75. **The Bellows.**—We have one other piece of apparatus with which we ought to be familiar, since it is found in almost every house.

In its simplest form (Fig. 146), it consists of two wooden boards connected by leather, the lower one being provided with a *valve k*, so as to admit air from the outside; the other with a hinge, allowing the top board to be raised or depressed.

FIG. 146.

The inside communicates with a piece of iron or brass tubing *d*, called the *nozzle*.

Now, when the top board is raised the *valve k* is lifted by the upward pressure of the air, which completely fills the space between the two boards.

When the top board is depressed the air within is *compressed*, which closes the *valve k*; at the same time the air is forced out through the nozzle *d*.

QUESTIONS UPON THE THIRTEENTH CHAPTER

Ques. 1. Explain the action of the *bellows*.

Ques. 2. Draw and explain the use of the syphon.

Ques. 3. Give a sketch of the *valve* employed in a common pump.

Ques. 4. What would be the effect of making a small hole at the highest point of a syphon?

Ques. 5. At the top of a mountain the mercury in a barometer tube stands at 25 inches; what effect would this have on the working of a syphon carried to the top?

Ques. 6. Could we use a syphon for conveying mercury from one vessel to another? If so, what limit would there be to the height of it?

Ques. 7. Explain how a squirt is made, and state why the water goes into it.

Ques. 8. Will a *syringe* work as well at the top of a mountain as it does at its base?

Ques. 9. Sketch and describe the action of a *suction* or *lifting* pump.

Ques. 10. What difference is there in the construction of a *force-pump* and an ordinary *suction-pump*?

Ques. 11. Describe the action of a common pump. To what height could mercury be raised by such a pump?

Ques. 12. Give a sketch, and explain the principle of action, of the force-pump. Also show by what modification a continuous stream may be obtained by means of it.

Ques. 13. What are the necessary conditions for a liquid to run from one vessel into another by the aid of a syphon?

Ques. 14. Explain the several uses of the *piston*, the *valves*, and the *air-vessel* in the force-pump.

Ques. 15. There is a limit to the action of the *suction-pump*. State what it is.

Ques. 16. Describe any modern improvement you may be familiar with for *starting* a syphon.

CHAPTER XIV.

GENERAL AND SPECIFIC PROPERTIES OF MATTER.

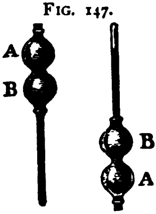
76. Porosity — 77. Compressibility — 78. Elasticity — 79. Tenacity — 80. Ductility — 81. Plasticity — 82. Malleability.

76. **Porosity.**—In the first chapter the pupil's attention was called to the difference between the **general** and **specific** properties of matter.

There the property of **porosity** was considered with regard to *solid* bodies only.

Here we propose to show that *liquids* and *gases* are likewise **porous**.

FIG. 147.



If a pint of water and a pint of alcohol be mixed together in one vessel, the volume of the mixture will be *less than* two pints.

How do we account for this?

Only by assuming that the molecules of one of the liquids have entered the space formerly occupied by the pores of the other.

Perhaps the following experiment will be of interest to the young reader.

A piece of glass is blown into the shape shown in Fig. 147, viz. into the form of two hollow globes A and B, terminating in a narrow stem.

First, fill the stem and the globe B with water, and then pour alcohol into the globe A.

Having closed it tightly with a cork, turn the vessel upside down, which will compel the alcohol to rise through the water, owing to its specific gravity being less than that of water.

The two liquids when mixed do not occupy the whole of the space they did at first.

FIG. 148.

This is seen by the empty space in the tube above the surface of the liquids.

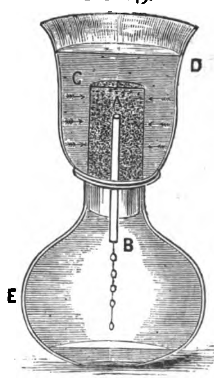
Again, *liquids* are known to be **porous** when they absorb *air* or any *gas*.

If we place a tumbler (Fig. 148) containing beer or ale under the receiver of an air-pump, and then deprive the receiver of its air, the liquor within the tumbler will expand, and a mass of froth will rise to the surface of the liquid to form a white head.

The production of froth is due to the *bubbles of air* or of some gas contained in the liquid, which are trying to escape at the surface.

A similar effect is witnessed when a tumbler of water is placed under the air-pump: the air-bubbles are distinctly observable as they leave the bottom and pass through the body of the liquid on their way to the surface.

FIG. 149.



Further, that *gases* are **porous** we can prove by placing a few grains of *iodine* into a Florence flask and corking it up tightly.

When heat is applied, the flask will be filled with a vapour of a beautiful violet colour.

The vapour of iodine has found its way into the **pores** of the air, as only the same space is given to the air and the newly formed vapour.

As an application of the **porosity** of *solids*, we give the ordinary charcoal filter, owing to its great utility (Fig. 149).

A glass bowl D is fitted with a cork in its bottom, through which a piece of glass tubing A B passes.

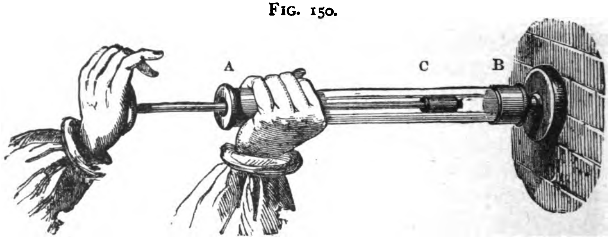
One end of the tube is inserted into a block of charcoal C, the other dips into an ordinary decanter E, upon which the glass bowl rests.

When water is poured into the bowl, sufficient to cover the charcoal, drops of water are observed to fall from the end B of the tube, having first passed through the **pores** of the charcoal to the end A of the tube.

77. **Compressibility.**—This is a property bodies possess when they can be reduced in volume or size without sustaining any loss of the material of which they are composed.

The *pneumatic syringe* (Fig. 150) furnishes us with an illustration of the **compressibility** of gases.

FIG. 150.



It consists of a thick glass tube A B, closed at one end, in which a piston C of leather works.

The tube being full of air, the piston is suddenly pushed forward ; the air within is thereby **compressed**, and gives up as much heat as will ignite a piece of tinder placed at the extreme end B of the tube.

When we consider the temperature at which this ignition takes place, viz. 300° C., we cannot doubt but that the effect of **compressing** a gas is to considerably increase its temperature.

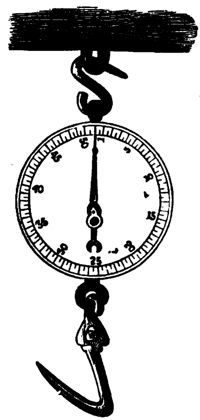
Lastly, there are bodies which are **compressed** with great difficulty ; among that number we include *glass* and some of the metals. In fact, the **compressibility** of solids is extremely small ; the **compressibility** of liquids, though greater than that of solids, is still very small ; while the **compressibility** of gases is something enormous, as they can be compressed into a hundredth part of the space which they occupy under ordinary conditions.

78. **Elasticity.**—This is a property which a body possesses when it is able to return to its *original* form and size, after having been pulled out of shape or altered in volume.

By far the greater number of solids exhibit the property of **elasticity** when the amount of *extension* or *compression* is but slight; a billiard ball, for instance, when allowed to fall upon a marble slab, rebounds in the same way as a glass alley does (*see* Fig. 4, Chap. I.), producing a similar ring upon the ink-covered slab.

Now, *putty* and *wet clay* are almost entirely destitute of this property, since a piece of putty or clay, rounded off like a marble and thrown upon the pavement, will present a flat surface at the place where it comes into contact with the ground.

FIG. 151.



Indiarubber, *ivory*, and *iron* possess considerable **elasticity**; likewise *steel*, especially after it has been tempered.

Use is made of the **elasticity** of steel in the construction of a watch, for by the **elasticity** of the *spring* the various parts are kept in motion. Likewise in fitting up carriages, perambulators, spring mattresses, chairs, couches, &c., we make use of this property of **elasticity**.

In the *spring-balance* (Fig. 151) and in the *letter-weighing machine* it is the **elasticity** of a steel spring which brings the index back again to the zero of the scale; in closing up a bottle with a cork it is the **elasticity** possessed by the cork which causes it to fit so tightly.

79. **Tenacity.**—This is a property found only in solids. It is, in fact, the resistance which bodies offer when an attempt is made to separate their particles by the act of stretching.

Some writers put it thus: The **property** which bodies possess when their molecules have the power to *hold fast* to each other is termed **tenacity**.

It can be experimentally shown in the following manner:—Take a number of different wires of the same length and of the same diameter, but of different materials, and suspend them to a horizontal bar.

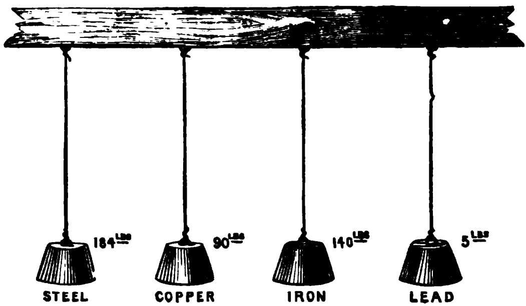
If weights be applied to the ends of these wires, we shall

observe that a different weight will be required in each case before the wires will break.

What does this prove? Is it not that the molecules have the power of holding on to one another with a different force in each wire?

To take examples: let the *four* wires shown in Fig. 152 consist of *steel*, *copper*, *iron*, and *lead*.

Fig. 152.



The weight required to break the lead being supposed to be 5 lbs., the weights for the other three will be, respectively, for *steel* 184 lbs., for copper 90 lbs., and for iron 140 lbs.

Thus we learn that *steel* is the most and *lead* the least tenacious of the four mentioned.

Similarly, if we were to contrast different kinds of *wood*, or *wood* with some of the *metals*, we should then see how much more tenacious some bodies are than others.

While *boxwood* stands a strain of 31 lbs., a piece of *mahogany* of the same diameter will break with a force of 11 lbs., or *tin* under a strain of 6½ lbs.

The shape of the body has also some influence on its resistance to breaking.

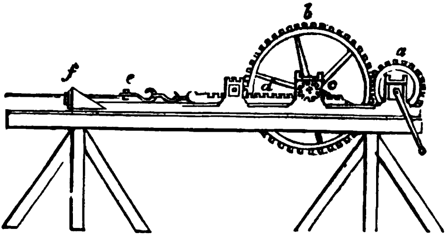
A *hollow* cylinder with the same amount of metal in it offers a greater resistance to breaking than a *solid* one.

It is for this reason that the bones of animals are much stronger than if they were solid.

As a practical application of the **tenacity** of steel, we might mention the wire ropes which are used for the rigging of ships, for supporting bridges, for raising weights from mines; *steel* being preferred owing to its great **tenacity**.

80. **Ductility.**—Wires are usually made by drawing the metal through holes in a plate, called a *draw-plate* (see Fig. 153, *f*).

FIG. 153.



The **property**, therefore, which a body possesses when it can be drawn out without breaking is termed **ductility.**

Among the most **ductile** of metals we have gold, silver, copper, and platinum.

Now, *platinum* is the most ductile of all the metals, for wires of this material have been obtained so fine that 1,060 yards of it weighed only $\frac{3}{4}$ of a grain.

One writer, in speaking of *platinum wire*, says that the threads can be obtained so fine that they are actually invisible to direct view; while another speaks of *platinum wire* being finer than a spider's web.

Wollaston succeeded in obtaining threads of *platinum* whose diameter did not exceed the three-millionth part of an inch.

Then, again, *glass* is so **ductile** that it can be drawn out into fine threads, and wound upon a reel as if it were ordinary thread.

81. **Plasticity.**—In the 'Potteries' this is a property very often called into use.

Whether this or that body is **plastic**? is a common question; that is, whether it is possible to make an impression upon a body that will remain after the pressure is withdrawn?

Take, for example, our coins. The impression on either side is made by placing the coin between two hard steel dies, and by subjecting it to great pressure.

Also, metal teapots are raised into their present form from a flat circular sheet of metal by subjecting it to pressure.

Boys may get an idea of this property by placing a gold

coin or a medal between two thin pieces of sheet lead, and by striking the lead with a heavy hammer.

Upon examining the two sheets of lead the impression of the coin or medal will be found upon them (Fig. 154).

82. **Malleability.**—If we trace the origin of this word, we shall find that the **property** is associated with the instrument employed to exhibit it.

Malleus, the Latin word for 'hammer,' gives us the word *mallet* also.

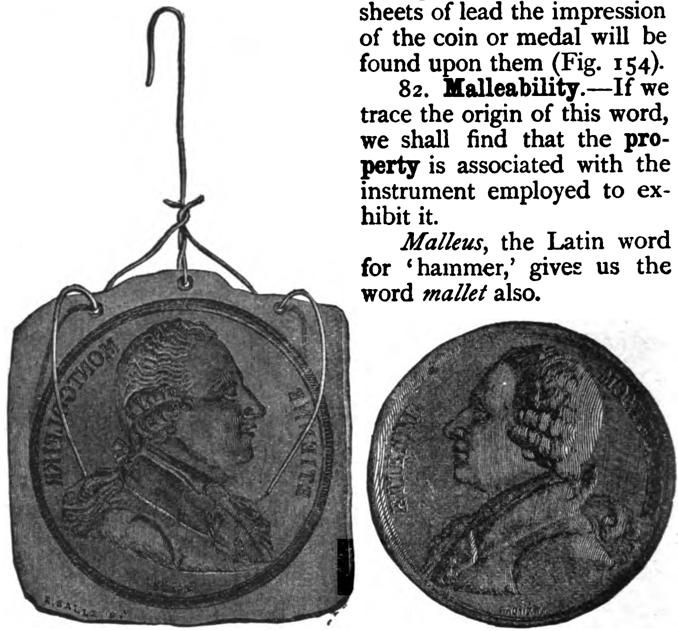


Fig. 154.

Hence the **property of malleability** is that which is exhibited when a body can be *hammered* out into thin sheets (Fig. 155).

Gold, we know, is very **malleable**, since sheets are obtained whose thickness does not exceed the three hundred thousandth part of an inch.

In that form it is known as *gold-leaf*, a square inch of which would weigh less than the twenty-thousandth part of an ounce.

Many years ago there was sent to England from Pittsburgh, in the United States, a letter written on a sheet made from iron, 1,000 sheets of which laid upon each other would only make one inch in thickness; the dimensions being 8 inches by $5\frac{1}{2}$ inches, or a surface of 44 square inches, and weighing 69 grains.

Since then Wales has surpassed America, Staffordshire has surpassed Wales, and Wales again surpassed Staffordshire, till at length Swansea has succeeded in making the finest and thinnest sheet of iron that has ever yet been produced, viz. 10 inches by $5\frac{1}{2}$ inches, or 55 square inches of surface, and yet only weighing 20 grains.

Tin is likewise expanded by rolling or hammering, or by a

FIG. 155.

combination of both, into sheets barely the one-thousandth part of an inch in thickness, under the name of *tinfoil.*

Lastly, *brass* is very **malleable,** and when beaten out resembles *gold-leaf*; so much so that a casual observer is in danger of mistaking the one for the other.

Brass in this form is known as Dutch metal.

QUESTIONS UPON THE FOURTEENTH CHAPTER.

Ques. 1. A sponge is a *porous* substance; what does that mean? Name any other three substances which are porous, but less so than sponge.

Ques. 2. What do you mean by bodies being *elastic*? What do you think of the *elasticity* of *putty*, *steel*, *glass*, and *lead*?

Ques. 3. What are *pores*?

Ques. 4. Does *porosity* exist in liquid matter? Prove your assertion.

Ques. 5. What is a filter? Draw one, and explain its principal parts.

Ques. 6. Make a diagram of a popgun, and explain its action.

Ques. 7. How could you prove that water is *porous*?

Ques. 8. What do you mean by *compressibility*? Name bodies which are most compressible and those compressed with much difficulty.

Ques. 9. There is a limit to the *elasticity* of solids. Explain this by illustration.

Ques. 10. How can you tell that a substance is *porous*? Mention three things that are *porous*, and state their other qualities.

Ques. 11. Show clearly that the rebounding of a ball is an illustration of *elasticity*.

Ques. 12. Explain the terms *ductile* and *elasticity*.

Ques. 13. Mention some bodies which have in a very high degree the properties of *malleability* and *ductility*.

Ques. 14. What use is made of the property of *plasticity*?

Ques. 15. What do you mean by a body being *tenacious*? Name *three* bodies which possess the property of *tenacity* to a large extent.

Ques. 16. Classify in their *order* of *tenacity* the following metals: brass, iron, steel, and lead.

Ques. 17. Mention any practical applications of the property of *malleability*.

Ques. 18. What are *gold-leaf*, *Dutch metal*, and *tinfoil*?

Ques. 19. Which possesses the property of *tenacity* to the greater extent, boxwood or mahogany?

Ques. 20. Sketch and describe the *pneumatic-syringe*. What does it illustrate?

CHAPTER XV.

MEASUREMENT OF TIME AND VELOCITY.

83. Ancient methods of measuring time: *the sun-dial*—84. *The water-clock*—85. *The hour-glass*—86. *Candle-clocks*—87. *Wheel-clocks*—88. *The watch*—89. The day—90. The week—91. The month—92. The year—93. Measurement of velocity.

83. **Ancient methods of measuring time.—The Sun-dial.** Not content with the natural divisions of the day and night, man must have early noted the varying lengths and turnings of the shadows of trees and rocks.

With the need ever comes the man to satisfy it, and observation prompted ingenuity to devise the *earliest time-measurer* in the **sun-dial**, the first mention of which is in the second book of Kings, chapter xx. verse 11, where we read that Isaiah the

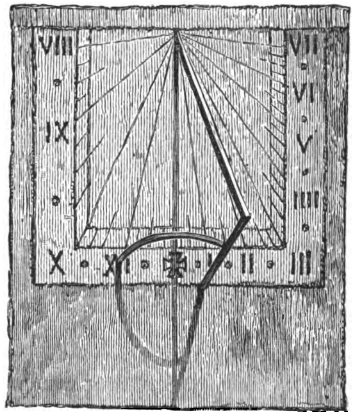
prophet cried unto the Lord, and He brought the shadow *ten degrees* backward, by which it had gone down in the **dial** of King Ahaz (B.C. 742).

The word *degrees* might have been rendered *steps*, for it has generally been supposed that a pillar standing outside the king's palace threw a shadow on the *steps* of the terraced walk, which indicated the time of day.

In Egypt obelisks and pillars were used to this end.

A yet more primitive mode of computing time is still pursued in Upper Egypt. The natives plant a palm-rod in the open ground, and arrange a circle of stones round it —forming a sort of clock-face—and on this the shadow of the palm falls, which marks the time of day.

FIG. 156.



Old Sun-dial, St. Catherine Cree, Leadenhall Street.

The plougher will leave his buffalo standing in the furrow to consult this rude clock, and then will learn how soon he may cease from his work.

The young reader may now ask, What is a **sun-dial**?

Well, in few words, we say it is a *timepiece of shadow*; but, instead of the shadows being thrown from trees, pillars, or buildings, we have a level surface, occupying perhaps a couple of square feet, upon which the shadow of a bar of iron, raised at a proper angle to the surface, falls.

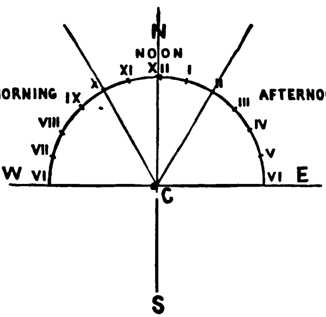
This **dial-plate**—for that is its name—is divided off at regular intervals, which show the places where the shadow will fall at each successive hour (Fig. 156).

For a class experiment it is advisable to take a sheet of paper and describe upon it a semicircle.

Through the centre of the semicircle C draw two lines at right angles to each other, so as to obtain the four points of the compass N., S., E., and W. (Fig. 157).

At the centre C let a penholder be placed so as to make an angle with the paper (the angle referred to corresponds with the latitude of the place, upon which we need not enter here).

FIG. 157.



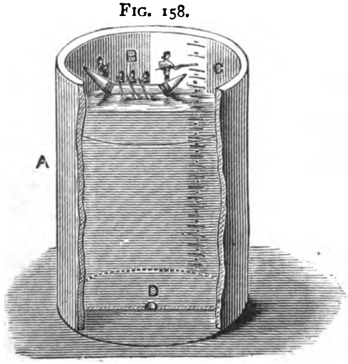
If the experiment be tried at ten o'clock in the morning, the sun, being then to the east of south, will throw a shadow to the west of north. At twelve noon, the sun being in the south, the shadow of the penholder will therefore be thrown northward.

Similarly, if we repeat the experiment at two in the afternoon, when the sun is fast approaching to the west, the shadow will be observed to be to the east of north.

Boys residing in London and in the 'Seven Dials' may wonder why 'The Dials' were so named.

The original 'Seven Dials' was a column standing in the parish of St Giles-in-the-Fields, where seven narrow streets all converged and left an open space, in the centre of which the pillar stood.

FIG. 158.



It had seven dial-faces, each a foot square, which were turned opposite to the respective streets.

In July 1773 it was removed, on the supposition that a considerable sum of money was lodged at its base, but the search was ineffectual.

The old column is now placed on the green at Weybridge, near Walton-on-Thames.

84. **The Water-clock.**—Long before the Christian era **clepsydrae** or **water-clocks** were in use. Since the sun does not always shine, it was found

necessary that some other means should be adopted to mark the flight of time.

The Egyptians seem to have hit upon the happy expedient of measuring time by the flow of water; for one Ctesibius, the son of an Alexandrian barber, who lived in the year B.C. 245, employed a jar containing water, which allowed the water to escape slowly by a hole in its bottom.

Perhaps Fig. 158 may give some idea of the contrivance just referred to, which consisted of a small boat floating upon the surface of water, and as this sank, an oar projecting from the boat pointed to the hours marked upon the inside of the jar.

Plato took the idea of the **water-clocks** from Egypt into Greece; he constructed one himself that played upon flutes instead of striking the hours.

The Greeks put them to good use by placing them in the courts of justice, to limit the length of the speeches of the various lawyers.

Julius Cæsar, when he invaded the shores of our island in the year 55 B.C., is said to have found a **water-clock** in use among the natives, and by the help of it to have observed that the summer nights in Britain were shorter than those of Italy.

Gifford, in his 'History of France,' thus describes Charlemagne's clock:—

'But what particularly attracted the attention of the curious was a *clock* worked by *water*.

'The *dial* was composed of twelve small doors, which represented the divisions of the hours; each door opened at the hour it was intended to represent, and out of it came the same number of little balls, which fell one by one, at equal distances of time, on a brass drum.

'By the eye it might be told what hour it was by the number of doors that were open, and by the ear by the number of balls that fell.

'When it was twelve o'clock, twelve horsemen in miniature issued forth at the same time, and, marching round the dial, shut all the doors.'

85. **The Hour-glass.**—Soon after the introduction of water-clocks another form of measuring time was discovered, and Alexandria boasts the invention.

This was the **clepsammia**, or **sand-glass**, which is more certain in its action than the **water-clock**, as under proper conditions sand will run more uniformly than water.

In Fig. 159 is shown one of these *time-measurers*, which consists of two blown-glass bulbs connected by a very narrow neck.

FIG. 159.

The sand being collected in one of the bulbs, it is turned upside down, and the time taken by the sand to fall through is carefully noted.

Formerly the time used to be one hour, but now they are so constructed that the sand will fall through in about three minutes, the time generally allotted for the boiling of an egg.

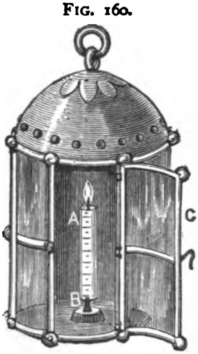
The **sand** or **hour glass** has been greatly honoured, for, besides being borne by the bald, bent, and decrepit form of old Father Time, it has been the stock-in-trade of poets from time immemorial. Now, alas ! it has dropped to the prosaic egg-boiler, and is even made to ring a bell, to jog the memory of the cook.

86. **Candle-clocks.**—These were among the various methods which were adopted by men in past ages to measure their time.

According to Asser, Alfred the Great, when a fugitive in his own country, vowed that if he should be restored to his kingdom again he would devote *a third* of his time to the service of God.

This vow he afterwards fulfilled by setting apart eight hours of the day to acts of religion, eight hours to public business, and the same number to sleep, study, and refreshment.

FIG. 160.



To measure and rightly divide his time, he adopted the following simple expedient : he procured as much wax as weighed seventy-two pennyweights, which he commanded to be made into six candles, each twelve inches in length, with the divisions of inches distinctly marked upon them.

These, being lighted one after another regularly, burnt four hours each, at the rate of an inch for every twenty minutes.

Thus the six candles lasted twenty-four hours, two monks being duly appointed to watch them carefully and act as snuffers, fingers being the instruments in use for the purpose at that period.

But when the winds blew, the air rushing in through the doors, windows, and crevices of his rude habitation caused his candle to gutter, and by fanning the flame to burn faster.

To remedy this, he caused some fine white horn to be scraped so thin as to become transparent, which he let into close frames of wood; and in these primitive lanterns his **wax-clocks** burnt steadily in all weathers (Fig. 160).

87. **Wheel-clocks.**—The date of the introduction of **wheel-clocks** and their inventor is uncertain.

One thing is certain, that clocks moved by weights and wheels were in use in the monasteries of Europe during the eleventh century.

What is now known as a **clock** was originally called a **horologe**, and the term **clock**, probably from the French *cloche*, a bell, was applied, down to the fourteenth century, to the bell rung to announce the hours.

In 1365, during the reign of Edward III., there was a *clochard*, or bell-tower, at Westminster.

This was taken down in 1715, and 'Great Tom,' the predecessor of 'Big Ben,' was given to St. Paul's.

One of the most important discoveries in relation to the history of clocks was that of the pendulum, which Galileo, the famous astronomer, in 1582 happened to make while engaged in the Cathedral in the contemplation of the lamps which swung by chains from the roofs.

He observed that their oscillations (movements forward and backward), whether great or small, were performed in equal times, the truth of which important fact he tested by the *beats* of his own *pulse*.

He afterwards discovered that the shorter the pendulum the less was the time of its vibration or *beat*.

A pendulum of 39⅐ inches will oscillate once in a second in the latitude of London; but if it were taken to the equator it would have to be shortened, or if to the poles, then it must be lengthened.

Likewise the material of which the pendulum is composed must be considered.

For instance, a wooden pendulum is superior to a metallic one, since *heat* and *cold* do not cause *the wood* to expand and contract as much as *the metals* do.

In speaking of the mechanism of a clock, we shall have to

single out *the pendulum*, *the weight*, and *the escapement*, since they form the principal parts.

FIG. 161.

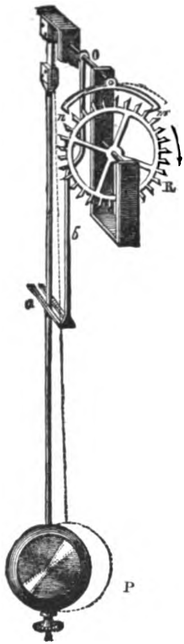


FIG. 162.

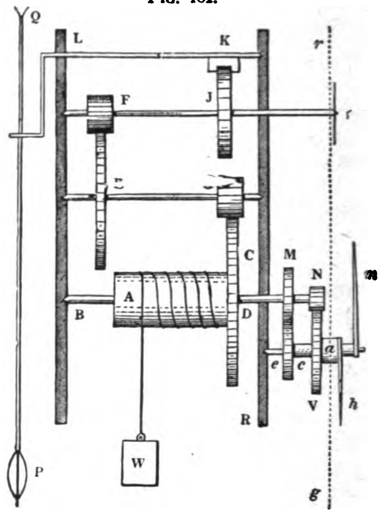
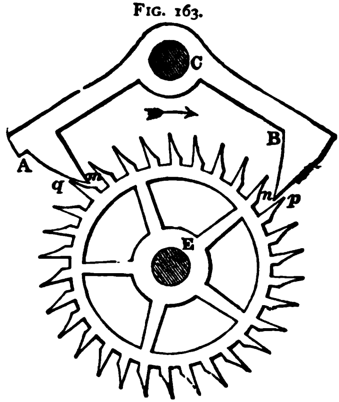


FIG. 163.



In Fig. 161 we have shown the **pendulum** P enclosed on either side by the forked piece of metal *a*, which is a part of the upright *b*; this upright *b* being secured to the axis *o*, which swings to and fro upon a horizontal axis.

To this axis is fixed a piece of metal terminating in the two projections A, B (Fig. 163), which form the pallets A *m*, B *n*, in the form of an anchor. The wheel E *p q* itself is termed the **escapement**.

Further, in Fig. 162 we have the train of wheels which serve to keep the **pendulum** in a state of motion.

In this figure a weight W is supported by a chain wound around the barrel A, which is always trying to revolve under the influence of the descending weight.

The cog-wheel C, which is attached to the same axis as the barrel A, will therefore give motion to the small wheel G; further, G and E being keyed to the same spindle, motion will be thus communicated to the wheel F. Now, upon the spindle to which F is attached the **escapement wheel** J is secured.

Thus we perceive that the weight W tends to keep the whole train of wheels from C to J in motion.

Here, then, the use of the **escapement** comes in, viz. to assist in regulating the speed of these wheels. Referring to Fig. 161, we observe the pendulum P in two positions: *first*, when the pallet *m* is actually in contact with the teeth; *secondly*, when the pallet *m* is away from it, during which period the *tooth* in contact has **escaped**.

In the next beat of the pendulum the pallet *n* arrests the motion of the **escapement wheel**, and likewise permits the descent of the weight.

In this manner the descent of the weight is **regulated**.

One other point is worthy of mention, which is this: should the clock *lose* or *gain*, what is the usual method adopted to rectify this?

From what has already been stated, we know that a pendulum to beat once in a second must be of a certain length, viz. about $39\frac{1}{7}$ inches.

If during the heat of the summer or the cold of winter the length be increased or diminished, then a corresponding difference of beat will be observed; in the first case the pendulum will move slower, in the latter faster.

This is rectified in many clocks by moving the bob up and down the wire of the pendulum; in other words, if the clock **gains**, the bob is *lowered*, to make a greater distance between the centre of the bob and the axis O; if the clock **loses**, the reverse is the case, for then we raise the bob, by which we lessen the distance between the bob and the same point O.

88. **The Watch.**—The latest and most convenient mode of measuring time is by means of the **watch**.

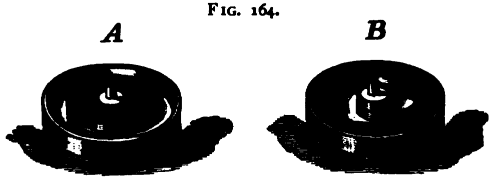
The word **watch** is derived from the Saxon *waecca*, to

wake; the Swedish *vacht*, watch or **guard**; or the Danish *vagt*.

The name **watch** was applied to **pocket-clocks**, because they were instruments by which the progress of time could be **watched** or noticed.

The first step towards watch-making was the invention of a coiled spring (Fig. 164) as the motive power in lieu of a weight, which is the source of motion in clocks.

FIG. 164.



The ancient German city of Nuremberg has always claimed the invention of **pocket-clocks**, as **watches** were at that time named.

89. **The Day.**—We now come to the various divisions of time. The first in order is **the day**.

Since the Creation man has been familiar with the succession of **day** and **night**.

It is only natural, therefore, that in selecting a period of time as a standard he should call into requisition some portion of time with which all are familiar.

Thus, **the day**, or the time which must elapse between the sun shining directly upon any one meridian on two successive occasions, came into use; or, in simpler language, **the time** that the earth takes to make a revolution upon its axis.

90. **The Week.**—This is not one of the great *natural* divisions of time, it simply being a period of seven days.

91. **The Month.**—This is a division of time regulated by the moon.

If we consider the time that must elapse between the appearance of one new moon and another, or, which is equivalent, the time that the moon takes to make a revolution round the earth, we shall obtain the **lunar month**, which is a period of $29\frac{1}{2}$ days.

92. **The Year.**—Here the sun determines this period of time.

We are all familiar with the seasons, Spring, Summer, Autumn, and Winter; but perhaps my young readers are not all familiar with the Spring or Vernal Equinox.

FIG. 165.

Twice in the year, in all places upon the earth's surface, we have equal day and night.

One of these occasions falls upon March 20, which is the Spring Equinox.

Now the period of time between one Spring Equinox and that of another is called **a year,** which, if expressed in days and hours and minutes, amounts to 365 days 5 hours 45 minutes.

93. **Measurement of Velocity.**—By the word **velocity** we usually understand the *rate* or *speed* with which a body moves.

Now when we attempt to measure it, two ideas present themselves: *first*, that of *time*; *secondly*, that of *space*.

I walk a mile. In what time? you ask. In 15 minutes. Thus the period of time required for me to cover the distance of one mile is 15 minutes.

More often, however, we require to know how far a body will move in one second or in one minute.

A ball is fired from the mouth of a gun at the rate of 1,000 feet per second.

By this we mean that in one second the ball would pass over the *space* of 1,000 feet.

Light and *sound* travel with different *rates*; in each case, however, the distance is expressed for the same period of time.

Thus light is computed to travel at the rate of 186,000 *miles* in one second, while sound scarcely travels 1,120 *feet* in the same time.

Again, a body may not move over equal distances in equal periods of time.

A rocket, when fired in the air, does not pass over equal

distances each second, for as it ascends it loses a part of its original **velocity** each second until it reaches its highest point; also when descending its **velocity** or rate is continually on the increase, eventually striking the ground with the same **velocity** as it had upon starting.

From this we learn that the motion of the rocket is not regular, and that the space passed over each second is not the same.

Velocity of this kind is termed **variable.**

On the other hand, we can understand that a body can be made to move over *equal* spaces in *equal* times.

A train, for instance, running along a level line of rails under the same pressure of steam, should pass over the same number of miles each hour.

When this is so, the **velocity** of the train is said to be **uniform.**

Or, take the case of the earth moving in its orbit around the sun.

We do not expect in one year the earth to move around the sun in 365 days and in the next in 465 days. No.

Astronomers tell us that, with very little error, the revolution takes place each year in 365 days 5 hours 45 minutes.

Advantage is very often taken of the difference of the rates at which **light** and **sound** respectively travel.

Try and think what 186,000 miles in a second really means.

We might just as well say, **light** travels **instantaneously.**

Further, we perceive a flash of lightning, but do not hear the rumbling of the thunder until five seconds have elapsed.

Knowing the **rate** at which sound travels, we are able to compute very nearly the distance the thunder-cloud is from us.

By multiplying 1,120 feet (the velocity of sound) by 5 seconds we learn that we are 5,600 feet from the cloud.

QUESTIONS UPON THE FIFTEENTH CHAPTER.

Ques. 1. Describe a sun-dial. In what respects are clocks and watches superior to sun-dials?

Ques. 2. A railway train travels at the rate of 40 miles an hour. What is the velocity in feet per second?

Ques. 3. One train travels at the rate of 45 miles in 75 minutes, another at the rate of 15 miles in half an hour. Compare their velocities.

Ques. 4. A marker by a rifle target hears the report of the rifle and the thud of the bullet on the target at the same instant. Explain this. If two seconds elapse between his seeing the puff of smoke and hearing the report, find approximately the distance of the rifleman.

Ques. 5. One train goes at 30 miles an hour and another at 25 miles. How many more feet a second does one go than the other?

Ques. 6. When may motion be said to be uniformly accelerated? The report of a cannon is heard $3\frac{1}{2}$ seconds after it is fired; about what distance separates the person who hears it from the cannon?

Ques. 7. The velocity of a train is 40 miles an hour. Explain this.

Ques. 8. Velocity is 'uniform' or 'variable.' Explain these terms. What is the velocity of light and sound?

Ques. 9. Two men start from London on a walking tour. One walks 150 miles in 5 days, and the other 175 miles in 7 days. Compare their rates of walking.

Ques. 10. Describe a sand-glass.

Ques. 11. A train goes 30 miles an hour; how many feet per second is this?

Ques. 12. What other ways of measuring time have been used besides clocks and watches?

Ques. 13. What is the most important part of the mechanism of a clock for regulating its going? What would you do if the clock went too slow?

Ques. 14. How could you find the depth of a well, knowing the *velocity of sound* in feet per second?

Ques. 15. Give the length of the pendulum which swings once in a second.

Ques. 16. Give an example of *variable* and also of *uniform* velocity.

Ques. 17. Explain fully how we get the following periods of time: *day*, *month*, and *year*.

Ques. 18. State what you know about the various kinds of ancient clocks used for measuring time.

Ques. 19. How is velocity measured?

Ques. 20. State what you know about the variation in the length of the day and night in different parts of the world.

EXAMINATION PAPERS.

SET I.

1. What do you understand by the *expansibility* of gases? How can you prove that *air* has weight?
2. There is a limit to the *elasticity* of solids. Explain this by illustration.
3. What do you understand by *molecules* and *atoms*? What do you mean by *molecular attraction*?
4. Explain the action of a barometer as a weather-glass.
5. Why will a *liquid* adhere to a *solid* more readily than *two solids* to each other? Illustrate this by example, and show that *adhesion* is greater than *cohesion* in the instance selected.
6. What is the rate at which *light* and *sound* respectively travel? Give an example of—

   (*a*) variable velocity,
   (*b*) uniform velocity,

   and explain them.

SET II.

1. What is a syphon? Explain how it acts and to what uses it is put.
2. Mention as many instruments as you can for measuring length.
3. Mention a substance that commonly occurs as a *solid*, a *liquid*, and a *gas*. How would you change a *solid* (1) into a *liquid*, (2) into a *gas*?
4. Mention two gases and their properties.
5. What is the meaning of the word *porous*? How could you prove that *water* is porous?

SET III.

1. A child's balloon inflated with air is thrown on the ground. Why does it rebound?
2. Distinguish between *cohesion* and *adhesion*.
3. Explain the action of the syphon.
4. Explain the construction and action of the force-pump.
5. How could you find the depth of a well, knowing the *velocity* of *sound* in feet per second?
6. A bullet is fired from a gun with a velocity of 1,000 feet per second. What is that in miles per hour?

SET IV.

1. If *iron*, *water*, *lead*, *mercury*, *butter*, and *tin* be made so cold that they are *solid*, and then heated, what will be the order in which they will *melt*?

2. How can you show that *coal-gas* is lighter than air? What use is made of this lightness?

3. A train goes 30 miles an hour; how many feet per second is this?

4. What is the effect of wetting a *porous* body? Give examples, and compare the action with that of a *capillary* tube.

5. Describe the construction and use of a thermometer.

6. What other ways of measuring time have been used *besides* the use of clocks and watches?

SET V.

1. Heat lessens the cohesion of solids. Explain this.

2. What do you understand by a filter? Explain its action.

3. Give an experiment to show that solids possess *elasticity*.

4. Why should a reservoir which supplies a town with water be placed upon high ground?

5. Show that there is an upward pressure in *liquid matter*.

6. The specific gravity of mercury is 13·5. Give an explanation of this. What is the standard of *comparison* for *gases*?

SET VI.

1. Describe the *properties* of salt, treacle, lead, and glass.

2. What is a *crystal*? What common substances form crystals?

3. Explain how a squirt is made, and why the water goes into it.

4. On one morning the thermometer shows $5\frac{1}{2}$ degrees below freezing-point, and in the afternoon it has risen 14 degrees. What is the tempera ture above freezing-point?

5. Describe a *sucker*, and explain why it can lift a stone.

6. Describe a sand-glass.

SET VII.

1. Sulphur exists in the *three states* that *matter* may exist in. Explain this.

2. There are *two kinds* of pores to be found. Explain this, and give examples. How can you find the *volume* of the pores of a piece of chalk?

3. Is gas a *fluid*? How can you prove that hydrogen can be poured upward?

4. What do you mean by *compressibility*? Name bodies which are *most compressible* and those *compressed* with *great difficulty*.

5. Name other ways of measuring time besides with watches and clocks. Give the *length* of the pendulum which swings once in a second.

6. Name parts of the body that have been used for measuring. How are bodies measured by *cubes*?

SET VIII.

1. Describe the *properties* of iron, sugar, chalk, and mercury.
2. How do you tell which is the *harder* of two solids? Put *iron*, *butter*, *lead*, *wax*, and *diamond* in their order of hardness.
3. Describe a spirit-level, and explain its use.
4. What does a barometer show, and what are the uses made of it?
5. What happens when a bladder *half full* of air is put under the receiver of an air-pump?
6. Describe the diving-bell.

SET IX.

1. Name any *likeness* and any *difference* existing between a *gas* and a *liquid*.
2. If hot water be poured into a cold glass the glass will probably crack. Account for this.
3. What do you understand by 'porosity'? How is it connected with the 'compressibility' of matter?
4. Give examples of the use of the terms *cohesion* and *adhesion*. What effect has heat upon the *cohesion* of solids?
5. Write what you know of a *sun-dial* as an instrument for measuring time. Explain the term *uniform velocity*. What is the velocity of (*a*) light, (*b*) sound?
6. What do you understand by a filter? Explain its action.

SET X.

1. Why does the blacksmith put the tire on a wheel when red hot?
2. Iron sinks, cork swims upon water. Why?
3. What is a filter? Draw one and explain its principal parts.
4. What do you mean by *atmospheric* pressure? Show that the atmosphere presses on a body, and to what amount.
5. Draw and explain the use of the syphon.
6. Draw a squirt (syringe), and explain how the water enters.

SET XI.

1. In what bodies may you say that molecular attraction *is balanced* by the repulsive force of heat?
2. Does *porosity* exist in *liquid* matter? Prove your assertion.
3. What explanation can you offer of the fact that a bent piece of whalebone tends to straighten itself?
4. What principle in the movement of *liquid matter* is at work in the playing of a fountain? Name other applications of the principle.
5. Velocity is *uniform* or *variable*. Explain these terms. What is the velocity of *light* and *sound*?
6. Why does the mercury in a barometer fall on being carried up a mountain?

SET XII.

1. Draw the diagram of a popgun, and explain its action.

2. Two men start from London on a walking tour. One walks 150 miles in 5 days, and the other 175 miles in 7 days. Compare the rates of walking.

3. What does the 'indestructibility of matter' mean? Show that matter is indestructible, using as an example the combustion of coal in a firegrate.

4. A boy dips one finger into water and another finger into mercury. What difference does he observe on taking his finger out, and how do you explain it?

5. A sponge is a porous substance. What does this mean? Name any other three substances also porous, but in a less degree than sponge.

6. What is the effect of heat upon solids? Explain the cracking of a glass when hot water is poured into it.

SET XIII.

1. Describe clearly what you saw in the bottle, stating what you learn from the movement of the drop of ink in the oil. Why is the drop of ink round? (A bottle was filled with oil, and a small drop of ink put in it.)

2. I drop a lump of sugar in my tea. State clearly what takes place. Why must I stir my tea before I drink it?

3. A chestnut put to roast on the fire suddenly explodes. Why is this? How could you prevent it?

4. Measure the box given you, and find its surface and cubical content. (An ordinary cardboard box was passed round the class.)

5. One train goes at 30 miles an hour and another at 25 miles. How many more feet a second does one go than the other?

6. Distinguish between *cohesion* and *adhesion*, and give an example of each.

SET XIV.

1. What measurements would you make to calculate the area of the top of a table?

2. How may a gas be converted into a liquid?

3. What instrument is used for measuring heat? How is it constructed?

4. What is the difference between *melting* and *dissolving*? Give examples of each.

5. What do you mean by capillary attraction? Give a few common examples.

SET XV.

1. The force of cohesion varies in different directions in the same solid. Explain this and give a few examples.

2. What is the principle on which fountains act? Illustrate by a diagram.

3. A cubic foot of water has been converted into ice. What changes has it undergone?

4. What do you mean by the volume of a box? What is the volume of a box which is 3 feet long, 2 feet wide, and 12 inches deep?

5. Describe an experiment for showing the upward pressure of the atmosphere.

SET XVI.

1. How would you determine the position of a series of solids with respect to their hardness?

2. How would you proceed to obtain crystals? Why do sugar-refiners crystallise their sugar?

3. What is adhesion? Why do we spread cement over the broken pieces of earthenware we wish to join together?

4. Draw a diagram of a syphon or an air-pump.

5. Describe a sun-dial. In what respects are watches and clocks superior to sun-dials?

6. What is weight?

SET XVII.

1. Describe a *water-level.* What is its use?

2. Carefully explain the method of determining the specific gravity of a solid.

3. What are crystalline bodies? Name some, and say how crystals are formed.

4. What is the difference between a *water* and a *mercurial* barometer? Would you require the same length of tubing?

5. Mention any experiments you have seen to prove that *the air* has pressure.

6. Gases have no cohesion. Explain this statement.

SET XVIII.

1. What do you mean by the 'divisibility of matter'? Give some examples showing the extent to which matter is divisible.

2. How is water supplied to houses in large towns? Illustrate by a diagram.

3. What is condensation? Give some examples from Nature.

4. Describe a barometer, and show how it may be used in measuring heights.

5. What is a gas? Describe the qualities of gases.

6. Describe a thermometer, and say what are its uses and how it acts.

SET XIX.

1. Show clearly that the rebounding of a ball is an illustration of *elasticity*.

2. Gases are highly compressible and expansible, but liquids are not. Show that you understand this statement.

3. What is the cause of weight? Show by an example that the weight of air differs according to its condition.

4. Liquids differ among themselves in the amount of cohesion they possess. Show by example that this is true.

5. If we suck one end of a straw, the other end of which is placed in water, why will the liquid rise into the mouth?

6. One train travels at the rate of 45 miles in 75 minutes, another at the rate of 15 miles in half an hour. Compare their velocities.

SET XX.

1. How is it that a drop of dye can colour a large quantity of water?

2. A glass stopper is fixed tightly in the neck of a bottle. On the neck being plunged into hot water the stopper may be removed easily. Explain this.

3. What do you understand by a vacuum? Give an experiment illustrating any result following on the making of a vacuum.

4. In using glue, what advantage arises from turning it into a liquid?

5. Explain the term 'specific gravity.' What was the discovery about specific gravity that was made by Archimedes?

6. What is understood by 'volume' and 'area'? Find the *area* and *volume* of a cube whose side measures $3\frac{1}{2}$ inches.

SET XXI.

1. How can you tell that a substance is *porous*? Mention three things that are porous, and state their other qualities.

2. What is meant by the *specific gravity* of a liquid? Mention some liquids of greater specific gravity than water and some less.

3. Describe a sun-dial. In what respects are clocks and watches superior to sun-dials?

4. Describe a thermometer and explain its action.

5. What is a gas, and what are the qualities of a gas?

6. Draw a diagram of a syphon or of an air-pump.

SET XXII.

1. Explain the following experiment:—A tube is partly immersed in ink, the finger is placed upon the top, the tube is raised, but the ink remains in the tube. But when the finger is removed from the top the ink falls out.

2. A book is passed round. Measure and state the area of the cover, and also the cubical content.

3. Steam issues from the spout of a tea-kettle. Why is nothing seen close to the spout? Is steam *solid*, *liquid*, or *gaseous*?

4. What is a crystal? Name some. How are they usually found?

5. Describe the *diving-bell*.

6. What is an alloy? Name two. What are the special properties of alloys?

SET XXIII.

1. Why do bodies float? Name some bodies that will float in *air*, *water*, and *mercury*.
2. Explain the terms *porosity*, *density*, and *elasticity*.
3. What is the *exhausting* and *condensing* syringe? Explain its action.
4. What was the great disoovery of Archimedes?

ANSWERS TO EXAMPLES.

CHAPTER V.

(5) 6 cubic feet.
(8) 245 square feet 78 square inches.
(14) 843*l.* 15*s.* 0*d.*
(15) 504 cubic inches.
(16) 240 square inches.
(19) 5280.
(20) 57*l.* 12*s.* 0*d.*
(21) 12*l.* 16*s.* $9\frac{39}{81}$*d.*

CHAPTER VII.

(17) 24 lbs.

CHAPTER VIII.

(6) $3\frac{1}{7}$. (9) $\frac{91}{100}$. (12) 1 oz. (13) 8·9.

CHAPTER IX.

(16) As 5 to 6. (17) 1·03.

CHAPTER X.

(3) $8\frac{1}{2}°$.

CHAPTER XV.

(3) 6 to 5. (5) $7\frac{1}{8}$ feet. (6) 3920 feet.
(9) 6 to 5. (11) 44 feet. (15) $39\frac{1}{7}$ inches.

EXAMINATION PAPERS.

Set III. (6) $681\frac{9}{11}$. Set IV. (3) 44. Set VI. (4) $8\frac{1}{2}°$.
Set XII. (2) 6 : 5. Set XIII. (5) $7\frac{1}{8}$.
Set XV. (4) 6 cubic feet. Set XIX. (6) 6 : 5.

Set XX. (6) $\begin{cases} 73\frac{1}{3} \text{ square inches.} \\ 42\frac{7}{8} \text{ cubic inches.} \end{cases}$

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